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# A Naval Aviation Maintenance Organizational Activity Strategic Information System (OASIS)

Chase, John H. Jr.

Monterey, California. Naval Postgraduate School

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# THESIS

A NAVAL AVIATION MAINTENANCE ORGANIZATIONAL ACTIVITY STRATEGIC INFORMATION SYSTEM (OASIS)

by

John H. Chase, Jr.

March 1990

Thesis Advisor: Martin J. McCaffrey



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Organizational Maintenance Activities (OMAs) within the Naval Aviation Maintenance organization do not have an adequate information system (IS). This seriously degrades their ability to efficiently and effectively manage their aircraft, equipment, and personnel. Information systems to support both Naval Air Systems Command (NAVAIR) and the operational chain of command include Naval Aviation Depot Information System (NADIS), Naval Air Logistics Data Analysis (NALDA), and Naval Aviation Logistics Command Management Information System (NALCOMIS). The portion of NALCOMIS intended to support OMAs is not scheduled to be fully implemented until 1999. Decisions made at OMAs have an immediate impact on force readiness and mission capability. Moreover, the largest unfulfilled need for information systems in the naval aviation community is at the OMAs. This thesis examines the history of IS in Aviation Maintenance, analyzes why OMAs lack adequate ISs, and offers a solution within the current technological capabilities of the aviation maintenance community. The potential improvement in operational readiness, avoidance of increased maintenance and personnel costs, improved decision making, and accuracy of information made available to all levels of the Navy chain of command makes implementing an Organizational Activity Strategic Information System (OASIS) imperative.

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# A Naval Aviation Maintenance Organizational Activity Strategic Information System (OASIS)

by

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B.S.E.E., University of Rochester, 1977

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requirements for the degree of

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# ABSTRACT

Organizational Maintenance Activities (OMAs) within the Naval Aviation Maintenance organization do not have an adequate information system (IS). This seriously degrades their ability to efficiently and effectively manage their aircraft, equipment, and personnel. Information systems to support both Naval Air Systems Command (NAVAIR) and the operational chain of command include Naval Aviation Depot Information System (NADIS), Naval Air Logistics Data Analysis (NALDA), and Naval Aviation Logistics Command Management Information System (NALCOMIS). The portion of NALCOMIS intended to support OMAs is not scheduled to be fully implemented until 1999. Decisions made at OMAs have an immediate impact on force readiness and mission capability. Moreover, the largest unfulfilled need for information systems in the naval aviation community is at the OMAs. This thesis examines the history of IS in Aviation Maintenance, analyzes why OMAs lack adequate ISs, and offers a solution within the current technological capabilities of the aviation maintenance community. The potential improvement in operational readiness, avoidance of increased maintenance and personnel costs, improved decision making, and accuracy of information made available to all levels of the Navy chain of command makes implementing an Organizational Activity Strategic Information System (OASIS) imperative.



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# I. INTRODUCTION

## A. BACKGROUND

Over the years a large organization has developed in the Navy dedicated to procuring aircraft, repairing those aircraft, ensuring the parts and associated aeronautical equipment are purchased to repair them, and managing the repair effort. Today, the Naval Air Systems Command (NAVAIR) encompasses every aspect of aviation in the Navy, from research and development, through procurement, to maintenance and servicing. NAVAIR, the Naval Supply Systems Command (NAVSUP), and various operational and administrative commanders constantly interact to ensure that operational readiness standards are designed into and maintained throughout the life cycle of each aircraft weapons system. Measuring and tracking operational readiness requires data and information about maintenance, logistics, and operations. Maintenance information includes data about the status of the aircraft and about what maintenance has been performed to achieve that status. Logistics information includes data about the location and estimated time of arrival of parts, personnel, and equipment. Operations information includes data about the flights flown and the missions performed by those units. This information forms the basis of future procurements (e.g., aircraft, spare parts, and people), current repair policies (i.e., fix it or scrap it), parts inventory stocking (i.e., how many and where), as well as which unit or aircraft to use for which mission and whom to assign to a particular maintenance action.

All aspects of Naval Aviation Maintenance are governed by the Naval Aviation Maintenance Program (NAMP) which was established by the Chief of Naval Operations (CNO) on 26 October 1959. The details of this program are promulgated in OPNAVINST 4790.2E [Ref. 1] which specifies the "policies, procedures, and responsibilities for the conduct of the NAMP at all levels of maintenance throughout naval aviation."

The NAMP is a dynamic program intended to take advantage of improvements in both technological and management methods and techniques. Information system technology has benefited from improvements in computer hardware technology, and Aviation Maintenance has taken advantage of those improvements to increase the capabilities of its hardware. However, information systems are not just hardware, but software and people as well. Software development is the acknowledged weak link in information systems development. "Computer hardware productivity continues to increase by leaps and bounds, while software productivity seems to be barely holding its own." [Ref. 2: p. 43] This has led to an estimated backlog of three to five years [Ref. 3: p. 323] which DeMarco says is "the fault of *inflated and unreasonable expectations*." [Ref. 4: p. 4] Naval Aviation has fallen victim to the same inflated expectations and poor software production problems described by Boehm and DeMarco. The most deficient aspect has been in the information system capability and support of Organizational Maintenance Activities (OMAs). OMAs are typically limited to a few micro computers, some office automation software such as wordprocessing, spreadsheet and database management, and maybe a terminal linking them to their immediate support activities.

## B. OBJECTIVES

The objective of this thesis is to start the process of providing OMAs with a much needed information system (IS). As with all such systems, the first step is a plan derived from an analysis of the information requirements of the OMAs. The key goal of the system is to provide the information required to the people who require it when they require it and in such a form that they can and will use it. It is more than just automation. It is a blueprint for long and short range system development. It will allow system growth to be managed rather than merely accepted by default. Current and planned information systems are included where warranted or dictated by NAVAIR policy. Several issues will be addressed, including:

- What are the strategic goals and missions of OMAs?,
- What information is required to achieve those goals?,
- Which, if any, current or planned systems should be included?,
- What interfaces with other systems should be included?,
- Should an Expert System (or several) be an integral part of the plan?,
- Should a Decision Support System (or several) be an integral part of the plan?,
- Who, i.e. what activity, should coordinate implementing this plan?,
- Who should be tasked with actual development?,
- Who should be tasked with post deployment support of the system?, and
- How will this plan be funded?

## C. SCOPE, LIMITATIONS AND ASSUMPTIONS

The proposed system is so large that this thesis will be able to address only design issues. The plan will include a proposal for the subsequent steps necessary for full implementation.

Descriptions of OMAs are based on the author's personal experience at two types of OMA, an Operations Maintenance Division and a Naval Aircraft Squadron, as well as on descriptions found in the literature.

Four four key assumptions of this thesis are that the Naval Aviation Logistics Command Management Information System for OMAs (NALCOMIS/OMA, or NALCOMIS Phase III) will not be implemented for several years [Ref. 5: pp. 13-14], that there is no interim alternative planned, that for the foreseeable future Organizational Maintenance Activities will continue to be without sufficient information systems capability to make the best possible use of their assets in meeting CNO operational readiness and safety goals, and finally that an interface between the proposed system (called OASIS), and NALCOMIS will be required.

## D. RESEARCH METHODOLOGY

Research into the current status of Navy systems, both fielded and under development, was conducted both in the literature and by telephone conversations with NAVAIR Program Manager Air 270 (PMA-270), NAVAIR code 41142F (Air-41142F), Naval Sea Logistics Center code 612.2 (NAVSEALOGCEN-612.2), Navy Management Systems Support Office code 51 (NAVMASSO-51), and Naval Aviation Maintenance Office code 02 (NAMO-02). Initial intentions to continue the work of McCaffrey [Ref. 6] and Allen & McSwain [Ref. 7] in the area of Expert and Decision Support Systems were overcome by the need for an overall information systems plan. Extensive telephone conversations between the author and NAMO 02 commencing in August 1989 confirmed this need.

## E. THESIS ORGANIZATION

The remaining chapters of this thesis are as follows:

II. Aviation Maintenance Organization. A general description of how the Naval Aviation Community is organized, with emphasis on the OMA and its role.

III. Information Systems. Definitions of different information systems, a brief history of information systems, areas of current emphasis in information systems, and a description of information systems in NAVAIR.

IV. Proposed Information System, OASIS. A brief discussion of strategic goals and functions, a review of NALCOMIS functions and modules, a description of the proposed OASIS modules, and a proposed implementation plan.

V. Recommendations, Further Research, and Conclusions. Recommendations about implementing OASIS, a discussion of areas needing further research, and conclusions.

# II. AVIATION MAINTENANCE ORGANIZATION

## A. THREE LEVELS OF MAINTENANCE

Aircraft maintenance in the Navy is separated into three levels, Organizational, Intermediate, and Depot. NAVAIR described the three levels in the *Naval Aviation Maintenance and Material Management Manual* [Ref. 8]. Organizational maintenance refers "to those maintenance functions normally performed by an operating unit in support of its own operations." [Ref. 8: p. I-4] The most common Organizational Maintenance Activity (OMA) is a squadron which is assigned a specific number of aircraft and people with which to perform its mission(s). Intermediate maintenance refers "to those maintenance functions normally performed in centrally located facilities." [Ref. 8: p. I-5] Intermediate Maintenance Activities (IMAs) typically support several operating units representing several different types of aircraft (e.g., E-2, F-14, A-6, F/A-18). Depot maintenance refers to maintenance functions performed in "industrial-type establishments," [Ref. 8: p. I-6] known today as Naval Aviation Depots (NADEPs). The most common of these functions is the overhaul, where an aircraft is taken apart, inspected, and reassembled with new or reworked parts.

The three levels of maintenance are based on the resources available at the activity (e.g., technical ability, facilities, and equipment). Maintenance functions are assigned to each activity by matching the resources required to perform the particular function with those available at the activity. For each type of aircraft,

the details of this breakdown of maintenance functions is developed during procurement and specified in the Maintenance Plan for that aircraft.

> The maintenance plan establishes and delineates the repairable components and maintenance requirements of a selected system or item of equipment. For each repairable component, the maintenance plan identifies the maintenance level authorized to perform the maintenance action indicated, and estimates the frequency of component failure or repair action. [Ref. 9: p.5-4]

There is no special relationship among OMAs, IMAs, and NADEPS other than that specified by their respective maintenance levels and unique capabilities. Any IMA is allowed to provide support to any OMA if it has the capability. Similarly, any NADEP is allowed to provide support to any IMA or OMA if it has the capability. Note that not all O-level[1] capabilities are assigned to all OMAs; nor all I-level capabilities to all IMAs; nor all D-level capabilities to all NADEPS. Each activity has its own assigned capabilities. For example, aerial refueling stores (ARS) are overhauled at NADEP Alameda, which has been assigned responsibility for all ARS.

OMAs are the operating units. They are the most mobile and consequently the least well equipped to perform major repairs. IMAs are located in major shore stations and aboard large ships, i.e., naval air stations & aircraft carriers, and have more in-depth repair capabilities than OMAs. There are six NADEPs, all located in the continental United States (CONUS). They all have the basic capabilities of an industrial manufacturing facility, as well as specific responsibility for various types of aircraft and equipment.

---

1 "-level" refers to the maintenance level normally associated with a particular maintenance capability--O-level to organizational capabilities, I-level to intermediate, and D-level to depot. For example, replacing the wheel assembly on an aircraft is considered an O-level capability, but replacing the actual tire on that same wheel assembly is normally an I-level capability.

## B. AVIATION MAINTENANCE PRINCIPLES

The *Naval Aviation Maintenance and Material Management Manual* [Ref. 8] prescribed "procedures for the management of aircraft maintenance and material at organizational and intermediate levels of maintenance." [Ref. 8: p. I-1] Specifically described are two broad areas of aircraft maintenance--a Planned Maintenance System (PMS), and a Maintenance Data Collection System (MDCS) [Ref. 8: p. I-1]. The stated objective of these systems was to "insure the highest state of aircraft readiness and reliability at the lowest cost in men, money, and material." [Ref. 8: p. I-3] The *Naval Aviation Maintenance and Material Management Manual* [Ref. 8] of 1967 has become OPNAVINST 4790.2E [Ref. 1] of 1989, but the objective is still "to achieve and continually improve aviation material readiness and safety standards established by the Chief of Naval Operations (CNO), with optimum use of manpower, material and funds." [Ref. 9: p. 2-1]

The Planned Maintenance System is a system similar to that provided by automobile manufacturers to their customers. The PMS is derived from the maintenance plan for that aircraft, and specifies that certain maintenance actions be performed at pre-determined intervals to ensure safe and efficient operation of the aircraft over its entire planned life[2].

Used by OMAs, IMAs, and NADEPs, the Maintenance Data Collection System is a system for collecting data about every maintenance action performed

2 The term "scheduled maintenance" refers to those actions performed at the prescribed intervals. "Unscheduled maintenance" refers to those "unplanned" maintenance actions performed when something breaks or doesn't work as intended.

on an aircraft or component of an aircraft. It also provides for collecting data about parts used, man-hours expended, and flight operations completed.

The *Naval Aviation Maintenance and Material Management Manual* [Ref. 8] also put forth two principles to ensure that the stated objective was met. Those principles are still applied today. First is the principle of "LOWEST LEVEL MAINTENANCE". This principle requires "that all aircraft maintenance be performed at the lowest possible level[3]." [Ref. 8: p. I-6] Application of this principle must be tempered by "optimum economic use of resources." [Ref. 9 p. 2-1] For example, buying a million dollar set of test equipment for every OMA if each OMA will use it only a few times a year is not an optimum use of resources. Instead, one such set should be bought, installed at an IMA, and used by the IMA to perform the required tests for several OMAs.

Second is the principle of "MANAGEMENT BY EXCEPTION". This means "that actions or incidents which vary markedly from certain standards or norms are singled out or 'excepted' from the whole for special management attention." [Ref. 8: p. I-6] The Naval Oil Analysis Program (NOAP) is a clear application of this principle. Oil samples are taken from components (mostly engines) and analyzed for traces of various metals. Depending on what metal and how much of it are present in the sample, certain actions are dictated. These actions range from just taking another sample to removing and replacing the component. This same principle is applied in a more macro sense to OMAs. Higher authorities won't interfere with the way an OMA is performing its mission unless the statistics reported about that OMA's performance and readiness be-

[3] The lowest level is the OMA, with the IMA and NADEP being progressively higher levels.

come an exception either to an established norm or to that OMA's own past record.

In short, the PMS specifies the minimum maintenance that must be done--the scheduled maintenance; the exception and lowest level principles cover the rest--the unscheduled maintenance; and the MDS records the data that describe all the actions pertaining to aircraft.

## C. ORGANIZATIONAL MAINTENANCE ACTIVITY

The Maintenance Department of an OMA is made up of several work centers, each of which specializes in performing a particular type of maintenance. For example, the powerplants work center will generally work on the aircraft engine and fuel systems. In the maintenance department, having aircraft ready to fly as published in the daily flight schedule is the dominating criterion for performing maintenance on aircraft. Coordinating all the efforts required to satisfy that daily flight schedule is a herculean task performed by the most experienced and senior enlisted personnel available, usually referred to as Maintenance Control Chiefs (MCCs). They work in a work center called, not surprisingly, Maintenance Control (MC). Figure 1 on page 11 is a diagram of the functional relationships within an OMA Maintenance Department.[4]

In addition to meeting the daily flight schedule, MCCs attempt to satisfy all the requirements of all higher authorities, as well as plan for all known future

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[4] This diagram is slightly different from the normal "organization chart" for an OMA, where MC is just another work center [Ref 10: pp.3-3,3-6]. This reflects the fact that Maintenance Control MUST control ALL aspects of the daily maintenance effort. The most obvious reason for this requirement is safety--having electrically activated hydraulic surfaces unexpectedly close on someone performing maintenance can be prevented when MC is in control because MC would know not to allow electrical power on that aircraft.

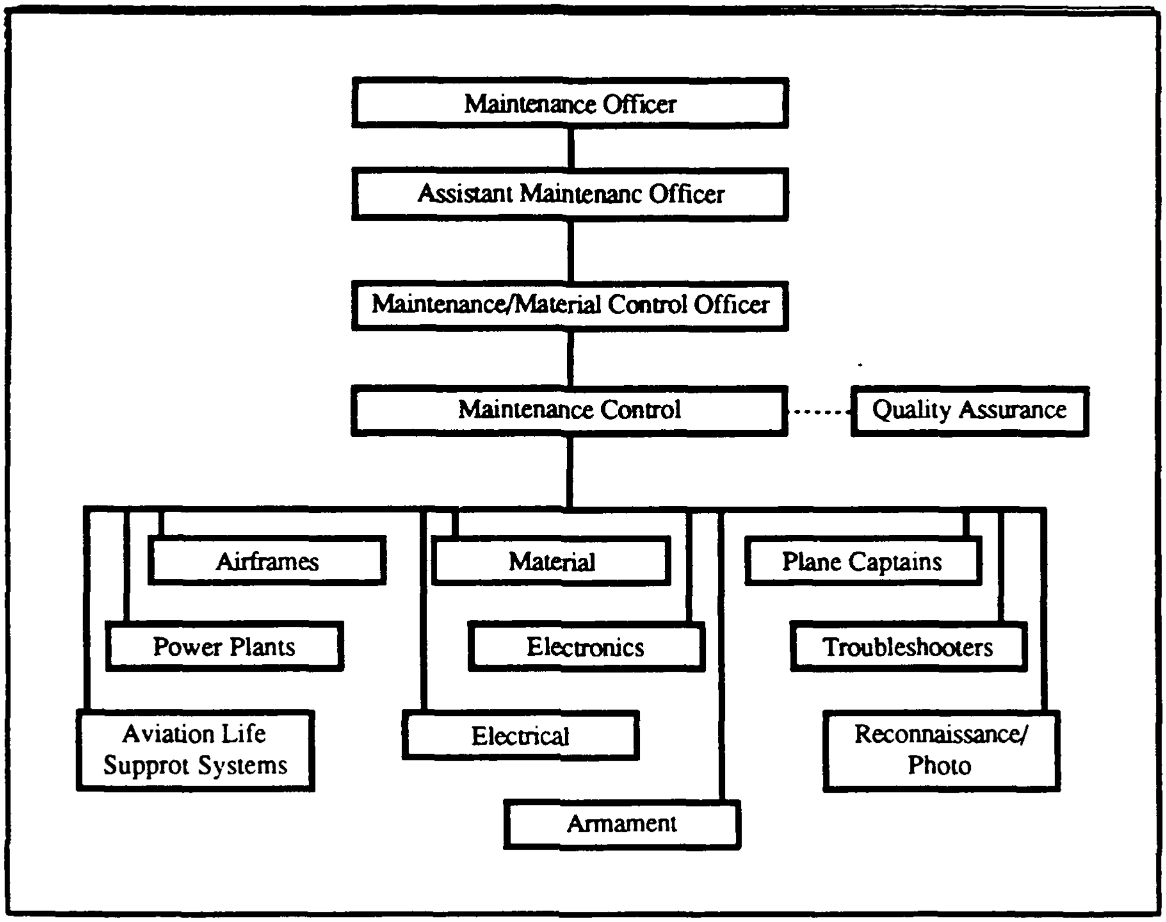


**Figure 1. OMA Maintenance Department Functional Relationships**

Adapted from [Ref. 10 : p. 3-3]

missions. Higher authority requirements are specified in various instructions including OPNAVINST 4790.2E [Ref. 1], Fleet, Type and Functional Commander instructions, squadron instructions and maintenance department instructions.

The MCCs typically manage the minute to minute maintenance, making decisions about which aircraft to repair, whom to assign to make the repair, and when to actually do so. Many factors enter into these decisions, including worker experience and training, availability of parts, availability of tools, sufficient time

to accomplish the repair, other demands on technicians, and the criticality of the specific repair to the OMA's immediate and long range missions.

Long range strategic maintenance planning is managed by the Maintenance/Material Control Officer, and, in those squadrons fortunate enough to have one, a senior Master Chief Petty Officer, known as the Maintenance Chief. In those OMAs without a Maintenance Chief, his function is performed by the most senior and/or experienced MCC available. Strategic planning includes such issues as:

- determining what mix of airplanes, people, and equipment to take on the next detachment/deployment,
- coordinating with an IMA or NADEP for aircraft repairs beyond the authorized capability of the OMA itself,
- deciding which Technical Directives (TDs) to incorporate in which aircraft, and when to do so,
- deciding what changes to make to the maintenance schedule to have enough aircraft available to take on the next detachment.

The quantity of information required to plan and accomplish both the minute to minute missions and the long range ones is quite large. Knowledge of every maintenance program, all governing instructions, each piece of equipment, and the abilities and availability of both people and equipment, as well as knowledge of every system in the aircraft are some of the key elements that must be factored into every decision. Add the one constant in aviation maintenance--change--and the possibilities are staggering. Aviation maintenance has done as well as it has for so long **ONLY** because the quality of the people in these critical MCC positions has been so high.

How much better could OMAs do if information systems were at their disposal? This question has been partially answered by McCaffrey [Ref. 6], Allen [Ref. 11], and Allen & Mcswain [Ref. 7] in their theses. These authors analyzed the benefits of improved OMA information systems in their particular area of interest--expert systems, NALCOMIS, and decision support systems respectively. The systems they proposed were not intended to be a complete OMA information system. Their proposals represent a portion of OASIS, and should be integrated with OASIS to form one overall Information System specifically aimed at OMA missions and goals.

## D. INFORMATION USERS IN AVIATION MAINTENANCE

Many people have a legitimate need for information about naval aviation, from those involved in direct aircraft maintenance at the OMA level, through the various chains-of-command, on up to the President and Congress. The demand for information has grown as the number, complexity and required administrative support of aircraft has grown. An example of the growth in demand for information is Congressional demand for reports from the Department of Defense, which grew by 2000 percent between 1970 and 1988 [Ref. 12]. Although not specific to Naval Aviation, this example is indicative of the growth in demand for information in general.

Information at an OMA falls in two categories--internal and external. Internal information is information intended for use within the activity to achieve its goals and perform its missions, whereas external information is information generated solely to satisfy a requirement imposed from outside the activity and has no value within the activity itself. This distinction does not preclude activities

from using information originally intended for others, i.e., an OMA using readiness information required by its operational commander, or an operational commander requiring information primarily intended for use by the OMA. Instead, the distinction will help in assigning priorities to the information requirements of OMAs.

An additional distinction must be made between data and information. Data are "raw facts in isolation....These isolated facts convey meaning but generally are not useful by themselves." [Ref. 13: p. 67] Information is

> ...data that has been manipulated so it is useful to someone...Information must tell people something they don't already know or confirm something that they suspect. It should be noted that one person's information may be another person's data. [Ref. 13: p. 67]

Implicit in these definitions is the fact that information in isolation is merely data and that a person is needed to attach meaning to information. Whether it be as routine as "John Doe is out sick today," or as sensitive as the most top secret intelligence, information has always been critical to managers and leaders. Today, information has gained widespread recognition as a strategic resource as important as, if not more important than, physical assets [Refs. 14, 15 , and 16].

Within the OMA, the information users include virtually every person in the OMA, from the Commanding Officer (CO) and Executive Officer (XO), through all the Department Heads, to the technicians repairing the aircraft. The CO wants to know what is happening in HIS activity. His questions include:

- How many aircraft are ready to fly?,
- How much money do we have left for fuel?,
- How many people are on leave, in school, or going on the next detachment?,
- What is the status of the investigation of John Doe's accident?,

- How many pilots will need swim re-qualification during the next detachment or deployment?

The Department Heads want to know the same things as the CO & XO, both to take care of problems before being asked for explanations, i.e., to give the CO & XO solutions rather than problems, and to better perform their own jobs. For example, the Maintenance Officer needs to know:

- Will a particular aircraft be ready to fly tomorrow? next week? for deployment?,
- Are the parts needed for the next detachment pack-up ready, or will they be?,
- Have the necessary schools been scheduled for technicians making the next deployment?,
- Are enough tools on hand to perform required maintenance?

In Maintenance Control all the same questions must be answered more frequently, as well as some more detailed ones. Examples are:

- What inspections are due today? tomorrow? next week?,
- When is the next major inspection due?,
- Does Power Plants have enough people trained to change three engines next week?,
- How long will it take to change the radio in aircraft 510?,
- Can supply get us a new radar receiver before the next aircraft launch, or do we take it out of another aircraft?
- Has the daily inspection been completed on the aircraft next to launch?

## E. SUMMARY

In summary, the naval aviation community can not perform its mission without the right information available to the right people when they need it. From the top planning and procurement level, NAVAIR, through the operational levels, to the lowest level of maintenance, the OMA, there are many users of in-

formation systems. Each of those users has his own requirements for both quantity, frequency and format of information. Information systems (ISs), the subject of the next chapter, are the tools used to satisfy those requirements.

## III. INFORMATION SYSTEMS

This chapter provides a general discourse of information systems (IS) and their history, a discussion of current emphasis areas on information systems relevant to OASIS (Organizational Activity Strategic Information System), including applicable development techniques and methods, and a review of information systems in aviation maintenance.

The principle function of information systems is to get the right information to the right people at the right time in a form that they will use. Stoner and Wankel say that "Only with accurate and timely information can managers monitor progress toward their goals and turn plans into reality." [Ref. 17: p. 619] Implicit in these statements is that an information system MUST be focused on the goals of the organization. If not, the IS merely drains the organization's resources. An organization can not long survive, or in the case of an OMA, achieve high readiness, by wasting resources such as capital assets, personnel time, management attention, operating costs, and productive effort on an IS that does nothing to achieve organizational goals.

Information has four basic characteristics--quality, timeliness, quantity, and relevance. Information must accurately reflect the situation it purports to describe, be in time for any necessary action to be undertaken, be of a quantity no more and no less than the manager needs or can process, and be relevant to that manager's organizational function [Ref. 17: pp. 620-621]. Any information system, to be of value to an organization, should emphasize these four character-

istics. This emphasis should start at the inception of an IS, continue through the design and implementation, and most importantly, be among the determining criteria for any "enhancements" added to the system during its life.

An information system is just a tool. As with all tools, an IS can be misused, abused, not used, or, as intended, used effectively to achieve the goals of the organization. Failure to keep the organization's goals and the characteristics of information in mind during IS development will virtually doom an information system to failure.

Five categories of information systems are relevant to OASIS. They are transaction processing systems (TPSs), management information systems (MISs), management reporting systems (MRSs), decision support systems (DSSs), and expert systems (ESs). Each of these will be discussed in the following sections. The purpose will be to establish some working definitions, place each in a historical perspective, add the current IS trends of relevance to OASIS, and finally to describe some applicable methods and techniques for development.

## A. DEFINITIONS

### 1. Information Systems

There are many definitions of information systems. In simplest terms, an information system is a means to get timely, usable information to the managers or the knowledge workers[5] who need the information. More formally:

> An information system is a subsystem of the business. Specifically it is a person/machine arrangement of components that interact to support the op-

[5] Knowledge workers are "...those people whose jobs involve the creation, processing, and distribution of information." [Ref. 13: p. 40]

> erational, managerial, and decision-making information needs of knowledge workers. [Ref. 13: p. 53]

All the following categories of information systems fit within this broad definition. The framework developed by Whitten, Bentley and Ho, Figure 2 on page 20, is useful for keeping these systems in perspective relative to each other. This framework is also useful for identifying the principle knowledge-workers that utilize and benefit from each type of system.

### 2. Transaction Processing Systems

A transaction processing system (TPS) is a system to record, store and process data representing events important to an organization. The "aim of record-keeping systems is the processing of high volumes of data, not providing support for decision making." [Ref. 18: p. 446] Transaction processing systems "include payroll preparation, account management, and savings account interest tabulations." [Ref. 18: p. 446] A transaction processing system is the foundation of an information system. Without the data a TPS collects and stores, there can be no information.

### 3. Management Information Systems

A Management Information System is a system that provides management the information (not just data) they need, in the form they need it, in time for them to use that information to the benefit of the organization. MISs are typically used to aid managers in making those decisions that occur regularly, and for which there are pre-defined procedures or rules. An MIS is "an integrated system for providing information to support the planning, control and operations

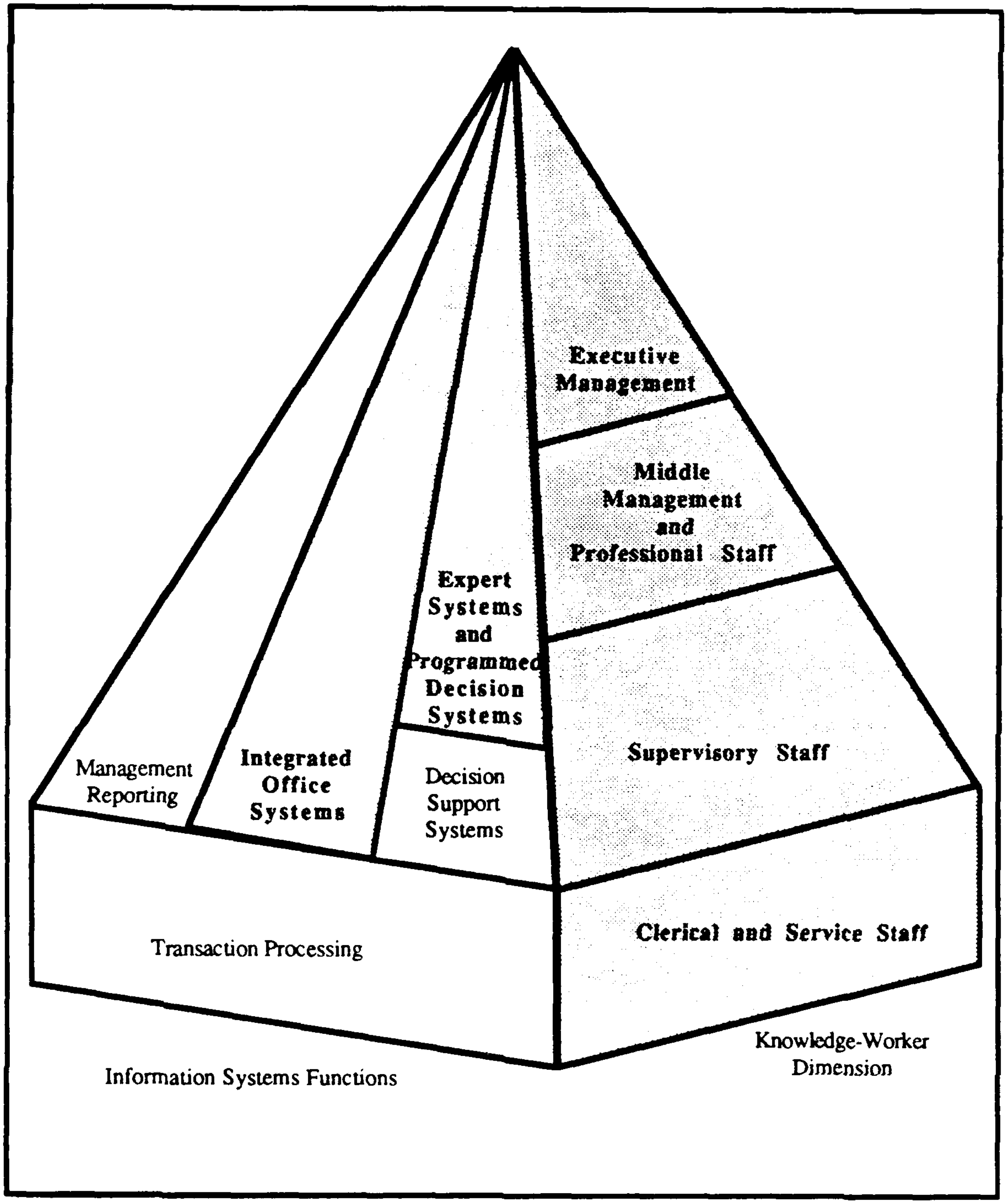


**Figure 2. Relationship Among Information Systems**

Source: Whitten, Bentley and Ho [Ref. 13 : p. 79]

of an organization." [Ref. 18: p. 498] A more rigorous and formal definition is that an MIS is:

> *a formal method of making available to management the accurate and timely information necessary to facilitate the decision-making process and enable the organization's planning, control, and operational functions to be carried out effectively.* [Ref. 17: p. 622]

### 4. Management Reporting Systems

Management reporting systems are systems which produce, at specified intervals, pre-defined reports based on the data collected and stored by its supporting TPS. There are three types or reports. The first is the detail report. This is simply a detailed listing of transactions recorded by the TPS. These are useful for transaction verification. The second report is the summary report. This is, as the name implies, a summary of the details of transactions. Summary reports are typically used to identify key items of interest to management, e.g., sales, interest paid or earned, profit loss, or outstanding orders. The third type of report is the exception report. This is a report to which some preset conditions have been applied as a filter, presenting the manager with only the exceptions to his predefined rules (filters). An example of such a report is a list of inventory items that are low and need to be ordered. [Ref. 13: pp. 71-73] A manager, by predefining the filter settings minimizes the time that must be spent manually filtering the data in order to obtain needed relevant information.

### 5. Decision Support Systems

Even though the term "decision support system" has been in use since the early 1970s, "there is still no strict definition of its meaning. For many writers, DSS is a philosophy, a way to seek a useful complementarity between technolog-

ical tools and human judgment and discretion." [Ref. 19: p. v] Sprague and Carlson, in what is considered the classic DSS treatise, say that "DSS comprise a class of information system that draws on transaction processing systems and interacts with other parts of the overall information system to support the decision-making activities of managers and other knowledge workers in organizations." [Ref. 20: p. 9] Bennett says that "A DSS is a coherent system of computer-based technology (hardware, software, and supporting documentation) used by managers as an aid to their decision making in semistructured decision tasks." [Ref. 21: p. 1] Turban provides what he calls a "Working Definition" of DSS:

> A DSS is an interactive flexible and adaptable CBIS [Computer-based information system] that utilizes decision rules, models and model base coupled with a comprehensive database and the decision maker's own insights, leading to specific, implementable decisions in solving problems that would *not* be amenable to management science optimization models per se. Thus, a DSS support complex decision making and increase their effectiveness. [Ref. 22: p. 73]

All of these definitions have two common threads. First is supporting the decision-maker in decision situations for which pre-defined procedures or rules do not exist or are incomplete, and second is improving the effectiveness of the decision-maker's decisions. A DSS is composed of three major subsystems, the Data Management Subsystem, the Model Management Subsystem, and the Dialog Management Subsystem [Ref. 20: pp. 28-35]. These are shown conceptually in Figure 3 on page 23. As DSSs are one of the more recent developments they are discussed in more detail in "2. Decision Support Systems" on page 33.

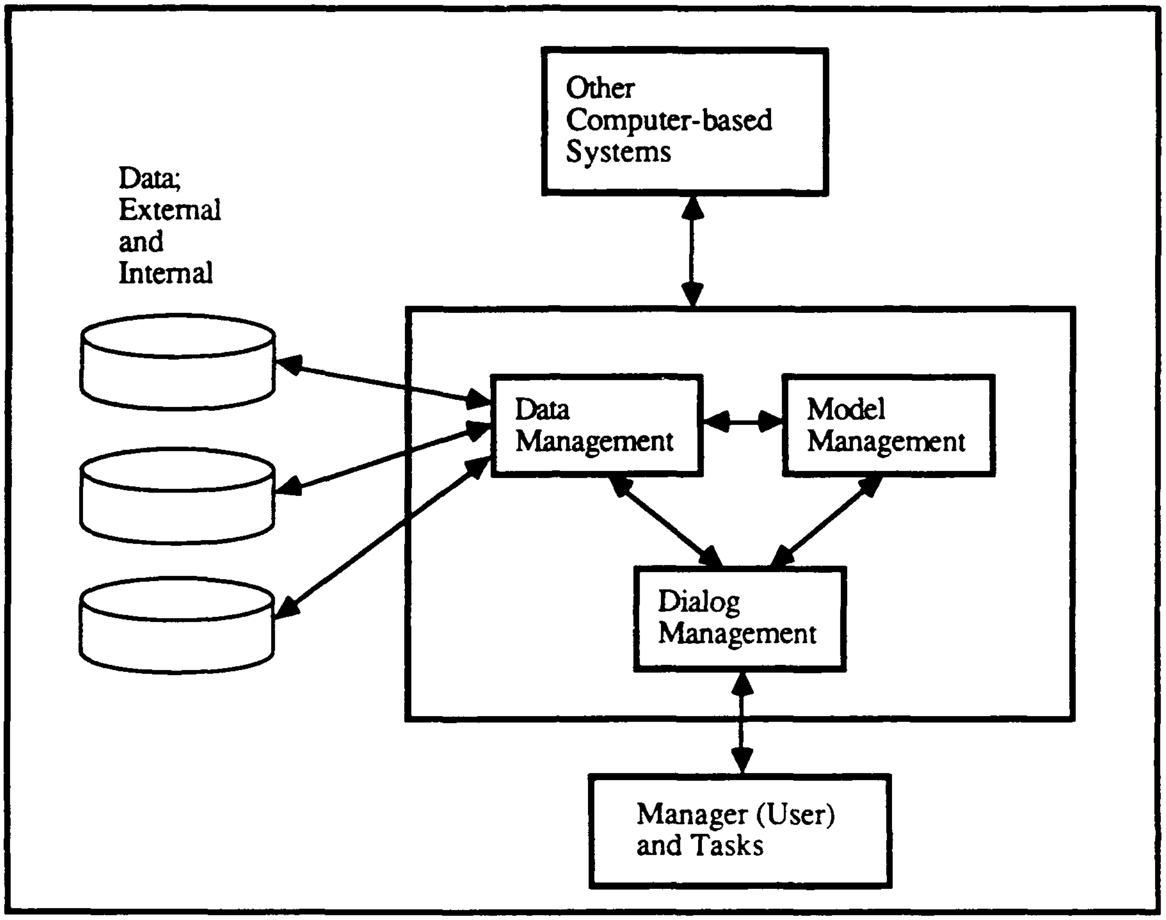


**Figure 3. Conceptual model of Decision Support System**

Source: Turban figure 3.2 [Ref. 22 : p. 75]

### 6. Expert Systems

Expert systems (ES) are the latest type of information system to be embraced by business organizations. An expert system is a computer based system used to consistently leverage the knowledge of an expert (or experts) to the advantage of an organization, independent of access to the expert(s). Because it is the latest bandwagon, many authors have jumped aboard, and definitions of ES abound. Turban says that:

> *Expert systems* are computerized advisory programs that attempt to imitate or substitute the reasoning processes and knowledge of experts in solving specific types of problems. [Ref. 22 : p. 321]

Whitten, Bentley and Ho say that:

> In an **expert system**, the expertise and knowledge associated with decision making is stored in a knowledge base. Programs are written to access the knowledge bases and databases to identify and make decisions.... [Ref. 13: p. 454]

Walters and Nielsen even eschew the term "expert system" in favor of "Knowledge-based systems" about which they say:

> In the simplest of terms, the notion behind knowledge-based systems is to capture the problem-solving *expertise* of a human being--an *expert* in a highly constrained problem area, called a *problem domain*--and *represent* this person's knowledge or expertise in a computer in such a way that the computer can approximate the expert's ability to solve a particular class of problems. [Ref. 23: p. 4]

An expert system is composed of three basic components. First is the knowledge base, made up of rules, heuristics and facts about the subject area. Second is the inference engine which contains the program with which the ES "reasons" and reaches a conclusion. Third are the interfaces that connect the inference engine to the user, knowledge engineer, and the explanation subsystem. The knowledge engineer is the person who gathers the expert's knowledge and converts it to the form needed by the knowledge base. Figure 4 on page 26 shows the typical organization of a knowledge based system. The components in the Development Environment are the tools used by the knowledge engineer or system developers. The Delivery Environment is what will actually be the knowledge-based system delivered to the user. As with DSSs, additional dis-

cussion of the aspects of ESs relevant to OASIS can be found in "3. Expert Systems" on page 35.

## B. BRIEF HISTORY OF INFORMATION SYSTEMS

### 1. The Business Focus

Information Systems (ISs) have always existed in one form or another. They have been used to gather. retain, and use information about something of interest to the user. In early society, people retained information about basic necessities such as where to hunt, which animals to pursue, and which plants were safe to eat. People still, in their personal lives, practice storing and processing information of interest to them. Libraries are another example of information gathering and storing. Today however, with many such basic "information systems" taken for granted, the term "information system" has come to mean a business-oriented computer based system.

The invention of the electronic computer in the 1950s brought a revolution to information systems. In what is called the "Computer Age," [Ref. 25: pp. 2-3] the computer changed the way data was collected and used. Rooted in the manual accounting systems of business, computer-based accounting systems took over gathering the data needed by owners and managers to measure the performance of their businesses. Business owners and managers asked such questions as:

- Were they making a profit?,
- Was the profit as much as the previous day? week? month? year?,
- Were their costs going up or down?,
- Was there a trend in sales, up or down?

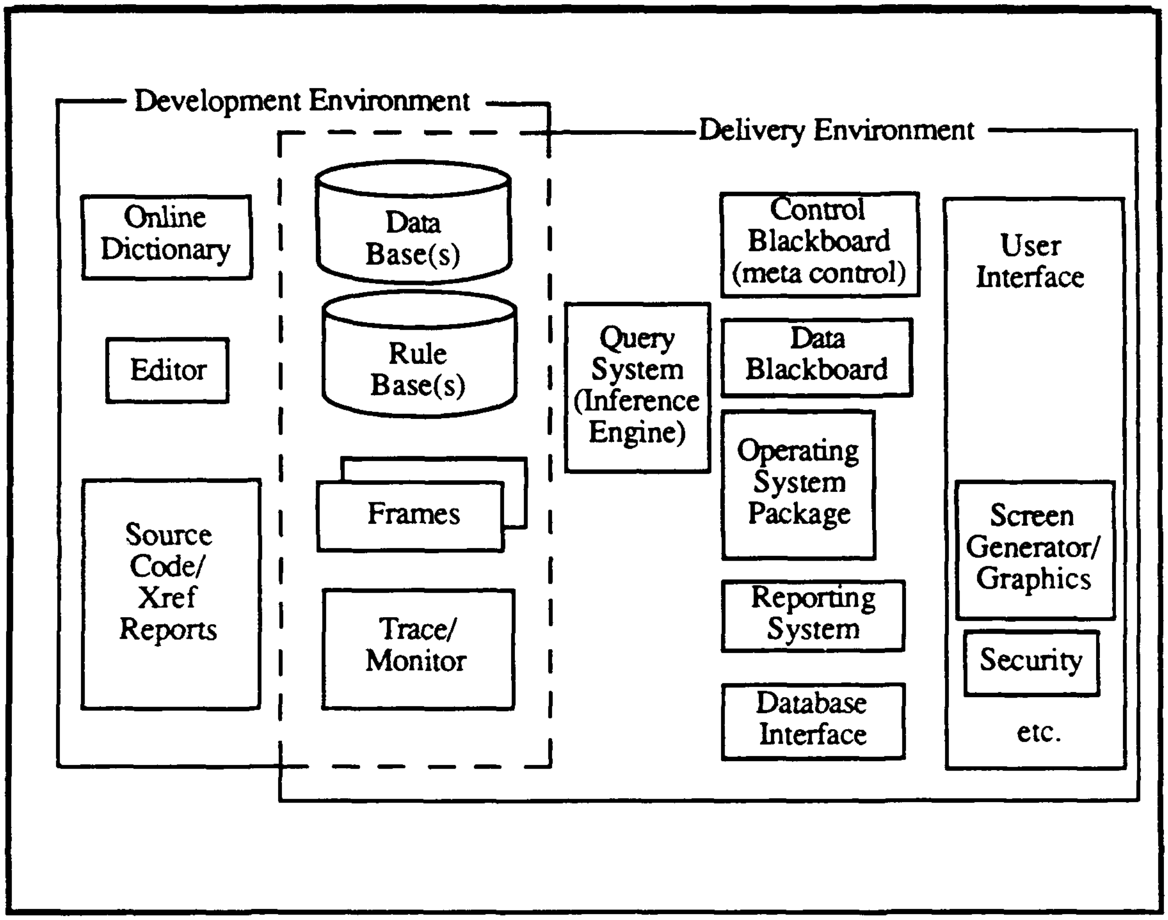


**Figure 4. Anatomy of a Knowledge-based System**

Source: Carrico, et al, Figure 1-2 [Ref. 24 : p. 5]

Computerized information systems, specifically accounting systems, provided answers, or the data from which answers could be derived.

One of the key characteristics of these early information systems was:

> ...their facility in dealing with well-structured and routine processes that computers can easily handle. The procedures may be repeated many times during the course of a day, week, or month. They are also well understood, to the extent that clearly specified procedures can be formulated. [Ref. 18: p. 446]

Since computers, with correct instructions, perform faster, more accurately, and more consistently than people, they were (and still are) used to perform the routine functions of storing, sorting, and summarizing the data collected in these accounting systems.

One of the reasons computers were accepted as information handling tools was the tremendous increase in the quantity of data being gathered, stored, and used. Manual information systems were unable to keep up. Entire computer systems had to be dedicated to the task of collecting data, manipulating that data in some fashion, and generating periodic reports based on the data. The systems built to perform these functions were, and still are called transaction processing systems (TPSs).

Transaction processing systems started as manual systems, and many manual systems are still in use.[6] The first computer based TPSs were frequently built simply to automate an existing manual system. Some people still think of TPSs as mere automatic manual systems. Senn, for example, says that "**Transaction processing systems** substitute computer processing for manual record-keeping procedures." [Ref. 18: p. 446]

In the 1960s and 1970s, as managers were inundated with rooms full of printed reports, they realized they were wasting their time trying to extract what they needed from those reports. What they really needed was information, not piles of data. Management information systems (MISs) were heralded as the solution to the data glut. MISs were made possible by a rapid improvement in

6 Some organizations have chosen, for cost, fear, simplicity, or some other reason, not to use computers.

computer technology and a growing knowledge of how to effectively apply that technology. In fact, advances in technology and knowledge made development of newer and better information systems inevitable. By their very name, management information systems offered management the promise of real information. Recall that information is "data that has been manipulated so it is useful to someone." [Ref. 13: p. 67] Developed principally to satisfy the need to reduce the large quantity of data to usable information, management information systems also allowed management to gain better control of the resources being expended on TPSs, e.g., capital and personnel.

Management Information Systems never fulfilled their promise. The "idea of building a single, integrated management information system (MIS) for any and all organizations...never really got off the ground." [Ref. 13: p. 116] Instead, MISs frequently became just management reporting systems (MRSs), in reality, little more than a TPS with better report generating capability. One of the reasons MISs failed to become all they were intended was the inability of management to define their requirements, and then to stabilize those requirements long enough for the MIS to be completed. Management's "information needs were so numerous, volatile, and diverse that it would take an enormous staff of analysts and programmers to fulfill." [Ref. 13: p. 116] This problem is not likely to change. Management's requirements are, of necessity, always changing to keep pace with their ever changing environment, and information systems must likewise change.

Another problem with MISs, and in fact with many information systems of the 1960s and 1970s, was inflexibility. The internal workings of computers are

quite rigid. A computer's representation of "w" is not the same as that for "W". This type of distinction is basic to a computer's operation, and therefore implies that once a system was implemented and being used, it could be adapted to new requirements only by a huge expenditure of additional resources. Consequently, attempting to "apply a very rigid, unforgiving technology to a very flexible and often unpredictable business situation" [Ref. 13: p. 115] met with limited success. This failure is attributed to trying to satisfy the needs of an "open system" with a "closed system." "An open system doesn't have well-defined interactions with its environment," whereas "A closed system has a precise number of well-defined inputs and outputs." [Ref. 13: p. 115] Since the application of a closed system solution to an open system problem didn't work well, another approach to using the technology was necessary.

Further developments in available technology, both hardware and software, continued to occur, and decision support systems (DSSs) came into being. Whereas MISs were aimed at the routine, well-structured decisions of middle managers, "DSS are focused still higher in the organization," and more toward less well structured decision problems. [Ref. 20: p. 7] DSS are " Dedicated to improving the performance of knowledge workers in organizations through the application of information technology." [Ref. 20 : p. 8] DSSs provide the user, manager, or knowledge-worker, with greater flexibility in data manipulation, and also extract data from various sources and generate reports on that data. In fact, DSS have added an "on demand" and "custom" report ability to the manipulating and reporting functions of TPSs & MISs.

### 2. Artificial Intelligence and Expert Systems

While the business oriented TPS, MIS, and DSS were evolving, a parallel evolution was occurring. At a conference in 1956 at Dartmouth College, Artificial Intelligence (AI) was "born." Artificial intelligence is "an umbrella term for a variety of fields of study that include robotics, cognitive science, vision systems, natural language understanding, sound recognition, and knowledge systems." [Ref. 24: p. 15] In spite of the similarity to humans, predictions that computers would be able to think and learn, and ultimately replace humans, proved premature. In fact, only in the past decade has AI enjoyed any significant commercial success, and that has been primarily in the branch of AI called Expert Systems. A key distinction between the business oriented systems (TPS, MIS, MRS & DSS) and ES is the means by which each solves problems. The business oriented systems apply a pre-defined step-by-step procedure, called a "program," to a set of data and arrive at some result. With ES, the procedure is not pre-defined. Rules, facts, and heuristics[7] are stored and invoked as necessary or applicable--not in any pre-defined specific order. The latter is actually the way humans think. We have stored a wealth of learned facts, experience-based heuristics, and known rules that we apply both to routine situations, such as driving a car, and to new situations, such as learning to drive a boat or an airplane. Some recent examples of successful ES applications include:

- an ES to generate "an hour-by-hour baking schedule", screen job applicants, and write labor schedules for Mrs. Fields, Inc. [Ref. 26: p. 1],

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[7] "*Heuristics*...are decision rules regarding how a problem should be solved." [Ref. 22: p. 50] They amount to "educated guesses" about the solution to a problem.

- Digital Equipment Corporation uses an ES (XCON) to customize the configuration of VAX and PDP-11 computers prior to manufacture. [Ref. 27, and 28],
- an ES is being used to help solve the African food shortage through aquaculture--fish farming [Ref. 29: p. 57],
- using an ES to optimize the use of limited satellite launching resources [Ref. 29: p. 58], and
- using an ES to plan the refueling of NASA's space shuttle [Ref. 30].

To date, most military applications in the literature are only prototypes, and a majority of those are in the avionics troubleshooting, fault isolation area where a substantial rule base can be defined. However, just putting the maintenance troubleshooting procedures (decision trees), written in the form of "if-then" rules, into the ES knowledge base is not all that is required. That is because "too many unexpected causes of equipment malfunctions cannot be anticipated in a traditional if-then rule-based...paradigm." [Ref. 31: p. 1335] Examples of such malfunctions include spilled solder, damage from other equipment, or spilled coffee [Ref. 31: p. 1335]. Some examples of the prototypes developed and published include:

- an ES to isolate faults in "the fuel system, the flight control system, the auxiliary power unit, and the avionics systems." of the Army's AH-64A Attack Helicopters [Ref. 32:. p. 43],
- a prototype ES to make maintenance personnel assignments for a helicopter squadron's many detachments [Ref. 33], and
- using an ES to find the cause of electrical or hydraulic system failures in the Navy's H-46 helicopter [Ref. 34].

## C. CURRENT EMPHASIS IN INFORMATION SYSTEMS

### 1. Information as a Resource

Most recent texts and writings about information systems begin by stressing the importance of information as a corporate resource. For example:

> In many organizations, the focus of information systems management has changed. In the past, the emphasis was primarily on managing computers and the technology to process information...the primary concern has shifted to the information in computer systems itself, and the need to manage it as a resource. ...information itself has become a strategic resource, requiring its own policies and procedures for management and control. [Ref. 16: p. 643]

> ...computerized information is a resource of high value to corporations and other organizations. [Ref. 15: p. xix]

Such thinking has changed the context in which organizations view information systems. Transaction processing systems for example are no longer an end in themselves. Instead, a TPS must be an integral part of an overall IS targeted at achieving one or more of the goals of the organization. Simply automating an existing system is not enough. Instead, every bit of data must in some way contribute to the success of the organization. This requires a reevaluation of the data being recorded. Claiming "we've always collected it" is no longer justification for including data in a system. In some cases a complete change in the transaction processing system, computer-based or manual, may be required. A TPS may be the foundation of any information system, but now an entire mission-oriented information system is built on that foundation. That system is based on the premises that information is one of the organization's limited resources and that all the organization's resources, including information, must be used to achieve organizational goals.

Information systems no longer merely record data and fill rooms with printed reports that are seldom used. Not only must they provide periodic printed reports, but now the reports must be provided on an ad hoc basis in an easy to use format. That format has even taken on many forms beyond the

simple columnar report. Today, information can be presented in a variety of media from print to video and sound. Graphic displays are commonplace, with even the most basic off-the-shelf spreadsheet package having some graphing capability. Formats for presenting information to the user are limited only by available technology and by the user's willingness to pay. Additionally, in those organizations that have matured in their use of information technology, information systems are even being used to gain and keep a strategic advantage in their business environment. A well known example is that of American Hospital Corporation. They use information technology to provide better service to their customers and thereby increase their share of the medical supplies market. [Ref. 3: pp. 217-234]

### 2. Decision Support Systems

Decision support systems (DSSs) started in the early 1970s, and are used extensively today. Some say that any system that helps a decision-maker make a decision is a DSS. Keen and Scott-Morton refined the scope of DSS in 1978 [Ref. 35]. Since then, much work has been accomplished, and DSS have taken on the definition stated earlier. As the reader will recall from Figure 3 on page 23, there are three subsystems in a DSS. The first, the Data Management Subsystem, typically has several elements, including a database, a database management system, a data directory, and some sort of query facility. This subsystem is intended to manage the data needs of the DSS and user. [Ref. 22: pp. 76-82] The Model Management Subsystem has comparable elements, a model base, a model base management system, a model directory, and a model execution, integration and command facility. [Ref. 22: pp. 82-83] The Model Management

Subsystem is intended to manage the assortment of models that a user may need to invoke while using the DSS. The Dialog Management Subsystem is "the software and hardware that provides the user interface for DSS." [Ref. 22: p. 86] The three key elements for the dialog component of a DSS are the language with which the user interacts with the DSS, the type of presentation the DSS provides the user, and the knowledge the user must possess to use the DSS effectively [Ref. 36]. Perhaps describing characteristics of DSSs will make the differences between DSSs and earlier information systems, i.e., TPSs & MISs, clearer. According to Turban DSSs have four characteristics. They are:

- "DSS incorporate both data and models."
- "They are designed to *assist* managers in their decision processes in *semi-structured* (or *unstructured*) tasks."
- "They *support*, rather than *replace*, managerial judgment."
- "The objective of DSS is to improve the *effectiveness* of the decisions, not the *efficiency* with which decisions are being made." [Ref. 22: p. 8]

Sprague and Carlson [Ref. 20] provide a framework for developing a DSS that they call **ROMC**. *Representations* are those things decision-makers use to visualize a particular problem; *Operations* are those actions taken with those representations (which include gathering and manipulating data); *Memory Aids* are those mechanisms used to help the decision-maker retain intermediate data from operations with representations; and *Control Mechanisms* are the mechanics used to control the representations, operations, memory aids, and interactions with each user. "The ROMC approach provides a *process-independent* (italics mine) model for organizing and conducting systems analysis in DSS." [Ref. 20: p. 102] The critical point is that the analysis and design of a DSS should be in-

dependent of all processes performed in the system being analyzed. Process modeling is the way traditional transaction processing systems (TPSs) have been analyzed. The tools of traditional systems development, such as flowcharts, dataflow diagrams, and entity-relationship diagrams are all process-oriented, and not appropriate for analysis of a DSS. [Ref. 20: pp. 94-102]

### 3. Expert Systems

Expert systems evolved from principles and techniques developed in the academic world of artificial intelligence. "Artificial Intelligence. To these words each of us brings his own definition." [Ref. 37] To some, AI conjures up the horror of computers run amok (remember HAL). To others, AI is something for academicians and computer "geeks," but is not real. The best perspective comes form Shipley when he says

> Because Artificial Intelligence is an ambition more than a product, the technologies and methodologies that grow out of this field are not AI. Instead, artificial intelligence research is leaving a trail of tools and techniques that are enhancing the state of the art in computer applications development but are in no real way intelligent themselves. Or, as the well-known adage in the AI research community goes, artificial intelligence refers to those things we don't know how to do today. As soon as we figure out how to do them, they won't be AI.
>
> The point may seem simple, but it is absolutely essential to understanding the misunderstanding, disillusionment, and initial failure of commercial AI. [Ref. 37]

Expert systems are in reality simply computer programs that manifest "some combination of concepts, procedures, and techniques derived from recent AI research." [Ref. 38: p. 5] They are the latest tool to become commercially available to information systems developers, and thereby, the end-users. However, the increasingly sophisticated IS users are unlikely to apply ES technology

just because it is new. "...people buy products to solve problems...they don't buy technologies...." [Ref. 37] End-users will evaluate ES on the basis of whether that ES can solve problems.

The principle benefit that aviation maintenance can derive from expert systems is consistently leveraged expertise. Consistent because an ES does not become fatigued, is not subject to high stress, and can't be distracted. Therefore, the mistakes that even experts could make when tired, stressed, or distracted would not be made by an ES, or by someone consulting an ES. This is not to say an ES is infallible. In fact, an ES is only as good as the expertise in its knowledge base, and that expertise is a function of the expertise of the original expert and the accuracy with which the knowledge engineer translated that expert's knowledge into an ES. Nor can an ES "know" everything, any more than a human expert. However, unlike the human expert, an ES has no ego to get in the way of saying "I don't know." Instead, depending on how the inference engine is "trained" to respond, an ES will either ask the user for more data, or provide the user a conditional response.

The leverage derives from the fact that once in the ES, the expert's expertise can be used by anyone, anywhere. The expert does not even need to be by the phone! Additionally, experts, rather than spending their time solving routine problems, are free to spend their time on those decisions for which the expertise has not yet been captured, or for which a computer-based system is inappropriate.

> "Expert systems free workers from more mundane tasks so that they can spend their time on more difficult problems or more creative endeavors. De-

cisions are made consistently from worker to worker, and the know-how of top employees and specialists can be distributed throughout the corporation.

Expert systems also translate directly into cost savings. An IBM diagnostic system saved $12 million per year...by avoiding misdiagnoses and the accidental disposal of good parts. DuPont, a true believer in expert systems spends an average $25,000 to build a system that promises an initial payback of $100,000." [Ref. 37]

So, by providing the expert's knowledge to a large number of organizations, in the form of an ES, we, aviation maintenance managers, in essence multiply the number of experts we have, AND use them more effectively.

Through the 1960s and 1970s, computers evolved in two directions. In the scientific and academic communities, the focus was on number crunching and artificial intelligence. In the business community, the focus was on automated accounting, financial reporting, and rudimentary information management. Today, as the integration of TPS, MIS, DSS and ES occurs in the "Information Age," we are beginning to re-unite those once separate paths of information systems development [Ref. 25: pp. 2-3].

#### 4. End-User Development

"One of the most exciting trends on the people front of information systems involves knowledge workers' participation in information systems development." [Ref. 13: p. 84] The proliferation of micro computers, coupled with an increase in computer literacy throughout the work force has brought about a phenomena called "end-user computing." End-user computing is not the same as end-user involvement. End-user involvement is exactly that, involvement. That is, the end-user provides the developers with the requirements, feedback about progress, and approval of the final system. End-user involvement has be-

come a requirement of all systems development projects.[8] On the other hand, end-user computing, or end-user development[9], is the end-user doing the development of the entire system themselves, with or without assistance from IS professionals.

> "...*end-user development*...Because the end-user totally controls the design effort, there is little need to go through a traditional systems design life cycle. Moreover, today, end-users are much more sophisticated about information systems than they were in the 1960s. Therefore, they can play a larger role in systems design.
>
> End-user development does not necessarily mean total end-user control of projects. There are ways in which end-user development can be assisted by professional systems personnel...." [Ref. 16: p. 423]

Whether it be development or involvement in development, the end-user is playing a greater role in building information systems to satisfy their own needs.

Some claim that end-user computing development will relieve some of the huge backlog[10] of systems under development. Others claim end-user computing will only make the backlog worse as IS professionals have to repair and maintain user "developed" systems. [Ref. 25: pp. 233-234] "In one-fifth of data processing shops, 85 percent of personnel hours are allocated to maintenance, leaving little time for new systems development." [Ref. 16: p. 420]

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8 With the advent of Total Quality Management end-user involvement has received increased emphasis. The end-user is the "customer" that the information system, and consequently the system's developers, must satisfy.

9 Some even differentiate between end-user computing and end-user development, claiming that end-user computing is merely using the computer, and end-user developing is actually developing computer-based information systems. The distinction is moot in this context.

10 The explicit backlog is that set of applications that has been formally stated and given to IS professionals to develop. The implicit, sometimes called "hidden", backlog is that set of applications that users would like, but haven't bothered to specify because the explicit backlog is so huge.

End-user computing is really just another part of the IS puzzle that will need to be nurtured, managed, encouraged and controlled. "It has become clear that techniques are needed for guiding end-user computing to prevent a Tower of Babel from springing up as a result of randomly designed data and redundant procedures." [Ref. 15: pp. 40-41] Many benefits can be gained from a carefully considered and nurtured end-user development environment. Conversely, the risks of not managing end-user development are also great.

*(1) Benefits.* "The primary benefits of end-user development are improved requirements determination, reduced application backlog, and increased end-user participation in and control of the systems development process." [Ref. 16: p. 489] Better requirements determination would occur because the users are the ones who know what they really want. If the end-users develop the system themselves, they can make assumptions and compromises appropriate to the importance of the application, without having to explain those assumptions to someone unfamiliar with their real requirements. In effect, end-users practice a development methodology called "iterative prototyping." (More about that in "c. Prototyping" on page 48.)

The application backlog, both explicit and implicit, of systems awaiting development will decrease as more users develop their own systems. Approximately 60 percent of IS professionals' time spent maintaining existing systems is spent on enhancements [Ref. 18: p. 711]. If users were developing their own systems to satisfy the requirement for the enhancement, IS professionals would be able to spend more time building new systems. The backlog is reduced

in two ways, end-user development, and re-directing IS professional's time from maintenance to new systems development.

Finally, the increased end-user participation and control occurs as the end-users become increasingly literate about systems development. The control is a natural by-product of increased familiarity and a "Gee, I can do that" attitude.

*(2) Risks.* End-users may not have the entire picture of the organization's functions. Consequently systems they develop may be based on incorrect assumptions about the business and its direction. [Ref. 18: p. 722]. The simplest example would be of a user developing a system to manage an aspect of the organization that is soon to be divested, closed or shut down. A product that is soon to be phased out is one such situation. In this case, the user's development time is lost as well as the opportunity for that user to be working on something else of real value to the organization.

Another risk is that end-users may use software inappropriate to their needs. [Ref. 18: p. 722] In such cases, the end-users' development time may be far greater than needed. They may find, after much effort has been expended, that they can't accomplish what they want with the software they've chosen. Now they must start all over with software better suited to their particular application. For example, someone who has experience with a particular spreadsheet package may try to develop a database application using that spreadsheet package. Although most spreadsheet packages have some database management capabilities, their primary focus is on spreadsheet applications, and

any database capabilities they have are limited.[11] Database management packages are particularly well suited for easy development of database applications. Much time can be lost finding work-around solutions in the spreadsheet software to problems that are handled as a matter of routine by database management software.

One of the major risks associated with end-user development is that standards of development, learned through the school of hard knocks by IS professionals, will not be followed. [Ref. 18: p. 722] Those standards could be incorrectly or inadequately applied by the end-users. An end-user developed information system that contains an incomplete data dictionary directory system (DD DS)[12] is an invitation to future disaster. A DD DS that does not contain all data elements or locations of these elements, when used to locate where in the IS a particular data element is used, could render any changes made based on the DD DS into time bombs. Subsequent users would faithfully use the results from the system never realizing that its accuracy and effectiveness had been compromised by the simple but incomplete change(s) made previously.

Another area of risk is that of the stored data itself. When there are many user developed systems, data is stored in all of them. Which of these

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11 The old conventional wisdom about trying to satisfy two or more objectives inevitably leading to one or the other or both of the objectives being compromised is particularly applicable to software packages.

12 A data dictionary is a dictionary of all the items of data used in a particular information system. It shows what the format of the data must be, and what the data element represents. For example, SSN is 9 numeric characters in the format nnn-nn-nnnn, representing an individual's social security number. The directory portion lists each and every use of that data element within a system thereby helping to prevent changes to the system from being incomplete, for example, changing an interest rate in one part of a system and not in another. Another function of the directory is to identify who, which person or office, controls the format and use of that data element. This to prevent changes that may impact other users of the system.

disbursed data bases has the current, correct information? [Ref. 18: p. 722] Who decides which system is the one to solve a particular business problem? How does a business integrate all the different user databases? If there is a central database, who is allowed access, either just to look (read only) the data, or to change (read/write) the data? These questions become more important as the size of organization increases and there is a corresponding increase in end-user development.

> Organizations must develop new policies and procedures concerning system development standards, training, data administration, and controls to manage end-user computing effectively. [Ref. 16: p. 490]

#### a. *End-user Computer Literacy*

The fact that computers have been around for years, and have infiltrated our schools means that as new people enter the work force they do so with less fear of computers and with a knowledge of what computers can do for them. This increased literacy is bound to lead to an increased demand for computers and computer-based applications that help knowledge workers do their jobs more effectively. For example, the Naval Academy now requires every student to have his/her own personal computer. This will have increasingly significant implications for what those students expect of the systems they use in the fleet. Furthermore, those computer literate students will form a talent pool in the Navy with the training and motivation to support information systems projects such as OASIS which is really a co-ordinated "build it ourselves" project.

#### *b. Increasing Power of Micro Computers*

It is no secret that the capability of a mainframe computer of 15 years ago is now contained in the micro computers of today. The speed and memory capacity of computer hardware has increased dramatically, sometimes even doubling in a few short years. Software, while not making such dramatic leaps as hardware has also made great strides. The ease with which users can learn and effectively use most software packages means that an end-user must no longer hold a degree in computer science. These two trends are making large mainframe systems virtually obsolete when it comes to satisfying small end-user requirements. Using to maximum advantage the increased speed, increased memory and more powerful software available in modern micro computers MUST be one of the principle criteria for any new information systems development.

#### *c. The Proliferation of Micro Computers*

Starting with the purchase of the Zenith model 120, micro computers have been the largest growing "population" in the Navy. One can't go to any command without finding some form of micro computer. Many of these tools have been pushed on small commands by higher authority--"Here you are, try to use it" approach. People in aviation maintenance tend to use everything at their disposal to accomplish their jobs. Their resourcefulness has its own legendary subculture. There are even tales of entire aircraft hidden away as spares. Although the publicity of recent years has changed things somewhat, manipulating the system to get whatever is needed to accomplish a mission is still practiced. Accordingly, when they were provided another tool, it was only a matter of time before they used it. The author is personally familiar with applications developed

by people in OMAs that track financial data, personnel assignments, training records, tool inventories, technical publications, flight hour accounting, as well as such simple things as pilot qualifications. Additionally, information systems have been and are being developed by students here at the Naval Postgraduate School, not to mention electronic bulletin boards that have sprung up for the exchange of specific applications that have been developed.

#### d. Development Backlog

As has been previously mentioned, a backlog of systems awaits development. The size of this backlog is typically measured in years. The most common range is three to seven years. What that means is that if one were to give a development project to a developer today, he would not even start for at least three years. To someone with a problem, such a delay is unacceptable. He will find another way to solve the problem. *"Users are accustomed to achieving goals in their own fields with a consistency that is unheard of in the software world."* [Ref. 4: p. 4] Consequently, many frustrated end-users resorted to building their own systems, becoming computer literate along the way. (Incidentally, the end-users in the fleet are used to meeting performance goals, e.g., readiness, MC, FMC, training levels, pilot training rate, far above anything that any information system provided or promised them has actually met.)

#### e. Concerns of IS Professionals

End-user computing can be perceived as both a threat to and a relief to IS professionals. On the one hand, their bad reputation for being late, over budget and incomplete with IS projects can only be helped if they have less backlog. On the other hand, if the end-users become proficient at developing

applications, IS professionals may see themselves being replaced. The reality of the situation is that the end-user doesn't want the IS professional's job; he just wants the tools to do his own job better. There will always be a need for a "better mouse trap", and even for the tools with which to build the better trap.

Since information has achieved status as a corporate resource, it must be protected as a resource. The security of the information is as important as the security of any other corporate asset. Proliferating micro computers make maintaining data/information security particularly difficult. A computer on every desktop provides the means of obtaining corporate secrets to any one who knows how to use the computer. A comprehensive security plan is now necessary to protect both the physical and electronic assets of the organization.

A closely related issue is that of data integrity. Who is allowed to change the data is particularly important, along with the timing and frequency of those changes. If two or more different copies of information somehow manage to exist at the same time, which one is correct or most current can be a particularly difficult problem to solve. It is only exacerbated with each additional micro computer. A closely related issue of ownership must also be addressed. The user, i.e., person, office, or command, that "owns" a particular bit of data or information is entirely responsible for that information. He

- establishes the requirement for that information,
- determines the format of that information,
- maintains the description and definition of that information,
- authorizes access to and use of the information,
- and authorizes changes to any of the above.

The concept of information ownership is important when designing an information system. Designers must work closely with information owners to ensure that the owners' requirements are met, while at the same time impressing on the owners the potential impact on the IS of any changes they, the owners, might make. Changing the format of a single data element such as a date could require changing storage formats, forms, and users' habits; moreover, the change will have ramifications proliferating throughout the organization. Information ownership carries the responsibility of deliberate change, if any, and long term stability.

Another very important issue is data administration. "*Data administration*...is concerned with the planning, administrative, and control functions for managing information...It is responsible for policies and procedures through which data can be managed as a companywide resource." [Ref. 16: p. 646] This is closely related to the data dictionary directory system discussed earlier. "Data administration is more organizationally or business oriented...." [Ref. 16: p. 645] Additionally, data and information, recognized as a resource, are being treated as a resource of the entire organization, not just one part of that organization.

> The most fundamental principle of data administration is that all data are the property of the organization as a whole. They cannot belong exclusively to any one business area or organizational unit. All data are to be made available to any group that requires them to fulfill its mission. [Ref. 16: p. 645]

The last concern of IS professionals to be discussed is that of end-user development running rampant with no guidance, no controls and few if any applied standards. As discussed in "(2) Risks" on page 40, these standards can have a significant impact on the system's performance and accuracy. IS profes-

sionals fear that end-users will buy anything and everything. Whether because it is the latest computer fad or because the end-users don't know any better does not really matter. The analogy of child in a candy store is apropos. The solution, as with the child, is to allow the growth of end-user computing within limits as long as the organization's missions and problems are being addressed by the growth. This concern may in fact not be long-lived. As end-users become more IS literate, they will be less likely to buy anything more than a solution to their particular problem [Ref. 37].

### 5. Techniques and Methods

Three techniques and methods are relevant to the development of OASIS. They are Structured Analysis and Design techniques, Information Engineering, and Prototyping.

#### *a. Structured Techniques*

Since TPSs were the first step in the evolution of computer-based information systems, a large body of knowledge exists today about how to design, build and implement such systems. A variety of methods and techniques to analyze and design systems, as well as a plethora of designers, and even entire businesses, are now available to support TPS development. [Refs. 2, 15, 39, 40 , and 41] Most emphasize the information requirements of an organization, and take a very formal, rigorous approach to modeling the existing systems. Several well known advocates are DeMarco [Ref. 4], Yourdon [Ref. 39], and Page-Jones [Ref. 40].

### *b. Information Engineering*

The second technique, in fact almost a philosophy, is Information Engineering (IE). The term "information engineering" implies the rigor and discipline associated with the more traditional engineering professions (such as civil, mechanical, chemical and electrical engineering). In fact, over the past decade, the development of information systems has progressed from the "art of programming" to a set of formal, rigorous disciplined techniques. Now, "the term *information engineering* refers to a set of interrelated disciplines which are needed to build a computerized enterprise *based on data systems*...The basic premise of information engineering is that data lie at the center of modern data processing." [Ref. 42: p. 92] IE had its origins with IBM's Business Systems Planning program in 1970 [Ref. 43]. Among the well known advocates of IE today are James Martin, Texas Instruments, and Clive Finkelstein. They all recommend concentrating on the organization's missions and goals instead of the existing systems, evaluating the data required to achieve those goals, and building information systems to provide and manage that data. In some cases, existing systems can be integrated into the otherwise all new IS. (This is what I recommend for NALCOMIS OMA. We have wasted enough time and money on it already. Let's not throw more at it. Instead, treat it as a 'sunk' cost and get on with what OMAs really need. Use what can be used from it, but most importantly, LEARN from the debacle so we don't repeat it!)

### *c. Prototyping*

A prototype is a one-of-a-kind type of item built to determine what is really needed. Prototyping then is the process of building a prototype, generally

with the idea, either implicit or explicit, of throwing it away once the real requirements have been determined. Prototyping provides a way to "buy" information from the end-users about what they really want. *"...plan to throw one away; you will, anyhow."* [Ref. 44: p. 116] There are now two approaches to prototyping, *throwaway* and *evolutionary* [Ref. 22: p. 150]. The evolutionary differs from the traditional throwaway in that it is intended to evolve, through as many iterations as necessary, into a deliverable system. There are several key benefits of prototyping--the iterations occur quickly; the users provide feedback on each iteration, and thereby stay involved in the development; and the cost is typically lower than traditional life cycle development [Ref. 22: p. 152]. A benefit of particular value to developing OASIS is a situation with many geographically disbursed users. In that situation, a prototype allows you to "get the idea out" to many of them, keeping many of them involved, and avoiding some of the "just another program form headquarters" acceptance problems.

## D. INFORMATION SYSTEMS IN AVIATION MAINTENANCE

### 1. Background

Information systems intended to make maintaining aircraft more effective and efficient have been under development for years. The Maintenance Data Collection System (MDCS) was developed to "insure that basic data generated by maintenance personnel are recorded once, and only once, and that the system (not the maintenance activity) thereafter provides information to all who have a need for it in such forms as may be useful." [Ref. 8: p. I-8] The MDCS became the Maintenance Data System (MDS) [Ref. 45]. Within this system coded data

describing every maintenance action is recorded on a form[13]. These forms are then collected, checked for accuracy and conformance to NAMP standards by an analyst at the OMA, and taken to a Data Services Facility (DSF) to have the data on them keypunched, i.e., entered into a computer system via keyboard.

The volume of these transactions is very large, and processing large volumes of data is "the aim of record-keeping systems." [Ref. 18: p. 446] Consider a hypothetical situation: there are 300 OMAs, ten aircraft per OMA, and each aircraft has, on average, five transactions associated with it daily. That would amount to 15,000 per day, and would not account for fluctuation. In a year there would be 5,375,000 transactions to be collected, stored, sorted and summarized. This hypothetical situation is less than what really occurs. There are really over 400 OMAs, and an aircraft with only five documented transactions per day is a very rare aircraft indeed. The MDS, of necessity, became a management reporting system, which at pre-specified intervals produces pre-defined reports based on the data collected and stored by its supporting TPS [Ref. 13: pp. 71-72]. It produces daily, weekly and monthly listings of all transactions, and summaries of those transactions for the OMAs & IMAs. When the stored data has been verified and corrected, summary reports are sent upline to higher authorities.

NAVAIR realized that the raw data being collected in support of aircraft maintenance was outstripping the ability of managers to assimilate it, and the sheer volume of data was making the reports and summaries less and less timely,

13 Even though it's called the MAINTENANCE Data System, the MDS collects logistics and operations data as well. Several forms are used in the MDS, including the Maintenance Action Form (MAF), the Support Action Form (SAF), and the Naval Flight Information Record (NAVFLIR).

and therefore of less value for making time-critical decisions. The batch processing[14] TPS just was not meeting the needs of all its intended users. In 1974, a Management Information System was conceived to allow data to be collected only once, and make information, instead of simply data, available to those who needed it, both the operating units and higher authorities. The Naval Aviation Logistics Command Management Information System (NALCOMIS), was intended as "a modern computer system to provide timely and accurate aircraft maintenance, operations, and logistics data." [Ref. 46: p. 1] NALCOMIS was aimed at supporting "day-to-day maintenance and supply activities," i.e., OMAs, IMAs, and Supply Support Centers (SSCs) in addition to satisfying upline reporting requirements of Navy and Department of Defense Program managers [Ref. 46: pp. 3-4]. Given the enormity of the tasks it was to perform, NALCOMIS was broken into three phases [Ref. 11: pp. 3-4]. Phase I was an interim system, implemented at only a few activities, called NALCOMIS Repairables Management Module (NRMM) [Ref. 11: p. 3]. Phase II addresses the information needs of IMAs and SSCs, and provides external interfaces to other related information systems such as AV-3M (Aviation Maintenance and Material Management), SUADPS (Shipboard Uniform Automated Data Processing System), UADPS (Uniform Automated Data Processing System), and of course, NALCOMIS/OMA [Ref. 47: pp. 36-37]. Phase III of NALCOMIS, also called NALCOMIS/OMA, was intended to automate the OMAs [Ref. 48: p. 3-1].

14 Batch processing occurs when "all data and transactions are coded and collected into groups (batches) before processing." [Ref. 18: p. 306]

### 2. Current Situation

Many information systems are intended to support the three levels of aviation maintenance. The Naval Air Systems Command (NAVAIR) is the principle sponsor of such systems.[15] The majority of information systems developed or planned for aviation maintenance have been large systems, i.e., requiring a mainframe or at least a mini computer. Until micro computers became capable of performing some of the required functions, building large systems was virtually the only way aviation maintenance could hope to reap benefits of computerized information systems.

Unfortunately, "...large systems development projects are often 30 percent over budget and require 50 percent more time than the early estimates developed in the project plan of a traditional systems life cycle. Unfortunately, large-scale projects have developed a reputation for being *much more costly, and much later, than expected.*" [Ref. 16: p. 418]

NAVAIR's Component Information Management Plan (CIMP) [Ref. 49] lists all information systems currently being planned or developed to support NAVAIR missions. The four "functional areas" for which information systems are being developed are:

- Logistics,
- Systems & Engineering,
- Contracts, Administration and Business, and
- Support Systems.

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15 The Naval Supply Systems Command (NAVSUP) has a vested interest in such systems since NAVSUP is tasked with material support of aviation activities.

As it turns out, "the majority of NAVAIR's current major ISs reside in the aviation logistics functional area." [Ref. 49: p. 1-11] This is not surprising, since NAVAIR's primary mission "is to provide for the full range of material support needs of the operating forces of the Navy for aeronautical weapons systems." [Ref. 49: p. 1-6]

Within the Logistics functional area, there are 26 different information systems described in the CIMP. They include local area networks (LANs) for specific commands, systems dedicated to supporting one level of maintenance, systems designed to address one aspect of aviation logistics support at all three levels of maintenance, and systems with requirements to provide extensive support throughout all of NAVAIR and the operating forces. Of those systems, three can have a direct impact on an OMA's ability to perform its missions. They are:

- Aviation Training Support System--Phase II (ATSS II),
- Naval Aviation Logistics Command Information Systems (NALCOMIS), and
- Support Equipment Resources Management Information System (SERMIS).

ATSS II "provides Fleet Readiness Squadrons (FRS) with an automated management support system to improve the efficiency of all aircrew and maintenance training." [Ref. 49: p. LOG-10] From the OMA point of view, ATSS II provides them with a record-keeping capability for the training records of their personnel. The primary intent however is to help manage the training evolution itself, and only peripherally to support the OMAs. SERMIS is a system intended to help Support Equipment Controlling Activities (SECAs) perform their mission of al-

locating, inventorying and reworking support equipment used by all aviation activities in the Navy. [Ref. 49: p. LOG-101] Again, accomplishing an OMA's missions is not the real purpose. NALCOMIS however, was intended from its inception to satisfy the information needs of organizational and intermediate maintenance activities throughout the Navy.

Of those described, only NALCOMIS was intended to provide aviation logistics, material management and administrative support to OMAs.

> There are four primary objectives of NALCOMIS, each of which has a major impact on the mission capability and overall personnel effectiveness at the Organizational Maintenance Activity (OMA), Intermediate Maintenance Activity (IMA), and Supply Support Center (SSC) levels in support of the Naval Aviation Maintenance Program (NAMP).
>
> The four objectives are:
>
> (1) Improved aircraft mission capability.
> (2) Improved aircraft maintenance and supply support.
> (3) Improved upline reporting to satisfy Navy and Department of Defense (DOD) program requirements.
> (4) Modernized management support. [Ref. 49 : p. LOG-81]

NALCOMIS is a very large system. The estimated total dollar requirement for the period FY88--FY94 is $204,333,000. When one recalls the reasons NALCOMIS came into being, and the number of transactions it was intended to handle, large was inevitable.

Large systems such as NALCOMIS, while seeming to provide an overall integrated system that realizes economies of scale, have by their very size not been able to take advantage of the tremendous increases in computer speed and memory, or of the decrease in physical size that have occurred. For example, when NALCOMIS was first envisioned, who could have realistically thought that 15 years later, all of the requirements could be satisfied by hardware and software

sitting on someone's desk. Such is the case, yet because of the magnitude of the project in 1976, and the technology then available, a development time of 15 years was unavoidable. If NALCOMIS were the only example of large systems development, then the fact that it has taken so long to field could be attributed to poor project management. Such is not the case. In fact, the entire information systems industry has been plagued by projects that are late, are over budget and don't perform as intended. "A construction job is considered a debacle if it overruns six percent." [Ref. 4: p. 4] It is possible that such projects were too ambitious from the outset. However, this author believes that the ambitious goals were not the problem, but that technology outstripped our ability to take advantage of it.

### 3. Previous Recommendations and Requirements

McCaffrey [Ref. 6], explored the use of an expert system for discrepancy scheduling with NALCOMIS. He concluded that an ES was both feasible and desirable. However, one of his premises was that the system would run on the same hardware as NALCOMIS/OMA. At the time, (1985), NALCOMIS OMA was scheduled to be implemented on a Honeywell mini-computer. McCaffrey's ES was intended to be run only two to three times a day, and because of the processing demands of the ES, would lockout other NALCOMIS processes while running.

Allen & McSwain, in their thesis [Ref. 7] carry McCaffrey's work further and propose something more than just an ES, specifically a DSS/ES for the MC arena. They offer a set of design, evaluation and implementation criteria. They recommend a prototype that addresses the problem of assigning aircraft to par-

ticular missions on the flight schedule based on the needs of the mission, and the mission capability of the aircraft.

## E. SUMMARY

In summary, information systems have evolved from manual transaction processing systems through computerized transaction processing systems, management information systems, decision support systems and expert systems to the integrated concept of today where an information system may include any combination of them. Information is now considered a resource. Information systems are the tools with which to manage that resource while focusing on accomplishing an activities goals.

Advances in technology have made the laptop of today the equivalent of the mainframe of 15 years ago. Software development has evolved to the degree that many consider it a field of engineering. Computer and information technology has moved from the back room to front office. Developing information systems has become less "art" and more "science." That science is being applied in many ways to benefit and improve the uses and development of information systems.

End-users are becoming increasingly willing and able to develop their own information systems. The tools for them to do so are readily available. So readily available that managing end-user computing has become a concern of information systems professionals.

Decision support systems and expert systems have become significant parts of many organizations information management. In fact, use of ESs is growing so rapidly that an organization that ignores them risks being at a competitive

disadvantage. The consistent leveraging of expertise is allowing organizations that do use ESs to produce better products and provide better services.

In spite of all the advances in computer and information technology, OMAs still do not have an information system. In spite of all the effort and money spent to get them one, they still lack the modern tool to effectively and efficiently manage their information as resource. Not only must managers at OMAs manage huge piles of paper searching for necessary but sometimes obscure information, but in this era of diminishing funding, they may have to manage with fewer experts as well. OASIS will fill this growing gap.

# IV. PROPOSED INFORMATION SYSTEM, OASIS

This chapter comprises the actual proposal for the Organizational Activity Strategic Information System (OASIS). First the strategic and functional requirements will be discussed, then the actual modules that should be implemented, then a preliminary implementation plan, and finally a discussion of potential problems and benefits.

## A. STRATEGIC AND FUNCTIONAL GOALS

The adage "If you aim at nothing, you'll hit it every time?" certainly applies to organizations. An organization needs to have some idea of what it is trying to do, and how it plans to do it. This "direction" of the organization should be explicit. In large organizations, such as the Navy, determining this direction is normally a formal planning process. The planning process should provide an organization with a statement of its goals in a form that can be used throughout the organization, a statement of its current situation relative to those goals, and a detailed plan of how it is going to achieve those goals. There are normally three steps to this process and they are:

- Goal Formulation,
- Current Situation Analysis, and
- Plan Formulation.

Goal formulation encompasses three basic activities; "...understanding the organization's purpose, defining its mission, and establishing the objectives that translate the mission into concrete terms." [Ref. 17: p. 123] Current situation

analysis is an evaluation of where the organization is now in relation to its goals, any identifiable threat(s) to achieving its goals, and any identifiable opportunities the organization should exploit. [Ref. 17: pp. 124-125] Plan formulation is where alternative ways of achieving the organization's goals are evaluated and the one the organization will follow is identified and promulgated throughout the organization. [Ref. 17: pp. 127-128]

An OMA's goals are derived from the objective of the NAMP, which "is to achieve and continually upgrade the readiness and safety standards established by CNO." [Ref 9: p. 1] Those goals are to:

- Increase efficient and economical management of human, monetary, and material resources,
- Ensure the maintenance, manufacture, and calibration of aeronautical equipment and material occurs at the level of maintenance that will ensure optimum use of resources,
- Ensure the protection of weapons systems components from corrosive elements through an active corrosion prevention program,
- Ensure the optimum application of a systematic planned maintenance program, and
- Collect, analyze, and use pertinent data to effectively improve material readiness and safety. [Ref. 9: p. 1]

Of these, the middle three are simply more specific sub-goals of the first. The last is the traditional goal of an IS, collecting and analyzing data. Placing it last should serve to emphasize that an information system is the tool for managing the information needed to achieve all the other goals, and nothing more.

The most important of the NAMP goals is the first. It identifies the three main categories of resources that must be managed. "Human" includes aircrew, maintenance and support personnel, AND their training; "monetary" at the

OMA is primarily concerned with operating target (OPTAR[16]) management; and "material" includes aircraft, ordnance, parts, supplies, publications and information. This division will form the basis for the proposed modules of OASIS.

A distinction needs to be made between the goals of an OMA and the goals of OASIS. An OMA's goal is to achieve and maintain CNO standards of readiness and safety. OASIS's goal is to help OMA maintenance professionals manage all their resources effectively so that the OMA's goal can be achieved. However, OASIS is an information system and as such OASIS must try to achieve the applicable goals published for all Navy information systems. Those goals are promulgated in SECNAVINST 5230.10, the IRSTRATPLAN [Ref. 50]. Although they are not the underlying reasons for developing OASIS, the IRSTRATPLAN goals for information systems must be considered. The seven goals of the DON IRSTRATPLAN are:

- "To enhance the productivity of DON components."
- "Make information technology a force multiplier."
- "Improve responsiveness to mission requirements."
- "Streamline the computer resource and information systems acquisition process."
- "Provide quality equipment, software and services."
- "Protect DON resources."
- "Maximize the exploitation of technology." [Ref. 50: encl. (1), pp. 13-18]

Having established the goals of OMAs and OASIS, the next step is to evaluate the current situation, specifically with regard to information systems for

16 An OPTAR is an operating target that an activity is given periodically by its type or fleet commander. It is an administrative limit on the amount of funds the activity can obligate from the operations and maintenance, Navy (O&M,N) appropriation. OMA's typically receive an OPTAR for flight operations, and an OPTAR for aviation fleet maintenance [Ref. 10: p. 6-132].

OMAs. Even though a more thorough evaluation might be thought necessary by some, the result will be the same. That is, OMAs do not have an information system with which to effectively manage information about all their resources. They may have parts of one, but not all OMAs have the same parts, and not all parts are the same. In other words, OMA "A" may have developed a spreadsheet to help track and manage its fuel expenditures, while OMA "B" may have developed a database to help track and manage the qualifications of its aircrew. Further evaluation should be done to establish exactly what has been developed, and the applicability of those applications to all OMAs. Such a study should also assess the hardware currently held by OMAs, so that budgeting to acquire any additional hardware could begin immediately.

Since so much effort has already been expended developing functional requirements for NALCOMIS, they should be reviewed and evaluated with the end-users for applicability to OASIS. A brief list of the NALCOMIS functions is extracted from Reference 46, page 4, and repeated here:

- "The proper identification of maintenance problems, along with the right maintenance skill and material to do the repairs...."
- "Verify repair completion and determine material readiness."
- Make the current workload readily visible to maintenance managers.
- Establish a maintenance schedule based on the "priorities of available resources including skills, worker hours, material and support equipment."
- Assist in the assignment of "properly skilled persons to perform maintenance actions."
- Provide supply and OMA maintenance managers with "timely notification" of material requisitioning and delivery.
- Provide OMA maintenance managers with the "availability and operability of aircraft."
- Provide summarized overall status "for management visibility in a timely fashion."

- Provide for tracking inventories of "repairable components, support equipment, component parts, requisitions, personnel, and maintenance capabilities."

The next section provides a brief review of the NALCOMIS subsystems. The following sections will describe the modules of OASIS, and address the last step in the planning process, formulating a plan composed of the objectives that add substance to the goals, i.e., the specific functions that OASIS will perform.

## B. NALCOMIS

To support the functions described in the previous section, NALCOMIS OMA was divided into ten subsystems. The brief descriptions in the following sections are extracted from Reference 46, pages 9-10.

### 1. Data Base Maintenance

This subsystem was to be the data base housekeeper. It "establishes and maintains the nonvolatile data within NALCOMIS and performs local data base support functions for all subsystems." [Ref. 46: p. 9] Such functions as purging no longer needed data and transferring data to historical archives were included.

### 2. Flight Activity

This subsystem was to collect flight hour data for use by other subsystems. The data collected is that which is now collected on the Naval Aircraft Flight Record (NAVFLIR) form. This data was to be used to track aeronautical equipment usage for planning scheduled maintenance.

### 3. Maintenance Activity

This subsystem was intended to "perform fully automated processing of the Visual Information Display System Maintenance Action Form

(VIDS/MAF)." [Ref. 46: p. 9] This subsystem was also intended to include the automation of the Support Action Form (SAF), and provide various reports to management to assist in "managing and monitoring" activities in the OMA.

### 4. Configuration Status Accounting

Configuration accounting refers to the process of maintaining a record of exactly what parts are in and what changes have been made to a particular item of equipment. Changes or modifications to aeronautical equipment are directed by what are called technical directives (TD) issued by NAVAIR. When changing components, knowing the particular configuration is critical to the successful repair. This subsystem was intended to automate the process of keeping configuration records for all aeronautical equipment.

### 5. Personnel Management

Knowing who is assigned to an activity, their qualifications, and the billet they occupy is essential to ensuring the right person is tasked to perform a particular job. This subsystem was intended to "collect and maintain specific personnel data for both military and civilian personnel assigned to an organization." [Ref. 46: p. 9] and thereby facilitate assigning the right person to each task.

### 6. Asset Management

This subsystem was essentially an inventory system for all aircraft and equipment assigned to an activity. Particular attention was given to the Individual Material Readiness List (IMRL) and the Aircraft Maintenance Material Readiness (AMMRL) Program. Today, the Support Equipment Resources

Management Information System (SERMIS)[17] is performing some of this function.

### 7. Local/Upline Reporting

This subsystem was to serve as the interface between other systems and NALCOMIS/OMA. It was to collect and accumulate information and then provide summarized reports to local management. In addition, higher authority reporting requirements of the NAMP would be satisfied by this subsystem. [Ref. 46: p. 10]

### 8. System Support

"Communication between organizations...through the maintenance of on-line messages." [Ref. 46: p. 10] was to be handled by this subsystem. This is what is now called electronic mail (E-mail). This service would have been provided to all organizations linked to NALCOMIS.

### 9. Data Offload/Onload

This subsystem was to provide the means to extract enter data about aeronautical equipment that was being transferred or received. An OMA has no need to maintain the maintenance history for an aircraft no longer in its custody. Similarly, the history of an aircraft newly assigned to the OMA needs to be added to that unit's data base. Rather than enter it by hand, this system allowed the data to be entered electronically.

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[17] As the reader will recall from "III. INFORMATION SYSTEMS" on page 17 SERMIS is a system to aid in managing support equipment at all aviation activities in the Navy.

### 10. Technical Publications

The technical publications necessary to maintain modern aircraft are voluminous. Maintaining an inventory of all of them, and where they actually are located is a job to which many people have been dedicated. This subsystem was intended to automate that herculean task.

### 11. Summary

NALCOMIS was an attempt to develop an information system, all at one time, as one overall project, to perform all of these functions. Trying to do it all at one time was, and still is too ambitious an undertaking. The details of just one function, flight hour accounting, are enough to keep several people busy ad infinitum with configuration management after deployment, not to mention the implementation itself. To realize the complexity of the procedures we are trying to automate, consider that Volume V of the NAMP [Ref. 45] is a document of over 700 pages that describes how the Maintenance Data System (MDS) works. More significantly, it specifies in laborious detail how to fill in the various forms used as source documents for the MDS.

We should learn from difficulties associated with the NALCOMIS effort and not try to accomplish too much all at once. *"The only unforgivable failure is the failure to learn from past failure."* [Ref. 4: p. 6] Any project for OMAs (including OASIS) should either be kept small, or divided into smaller projects and implemented one at a time.

## C OASIS MODULE DESCRIPTIONS

The modules proposed for OASIS are similar to those once proposed for the now defunct NALCOMIS OMA (at least defunct as originally envisioned [Ref.

51]), but are organized to be more consistent with an OMA's primary goal: optimum management of human, monetary and material resources. They are presented hierarchically in Figure 5 on page 67.

Without people to operate and maintain them, aircraft will not fly, therefore those modules dealing with human resources are addressed first. In view of current events in the world, and the much discussed "peace dividend", the second priority is monetary; thus those modules are described next. Third, the modules that are probably the most difficult to develop, those that address the management of material, from aircraft to piece parts, are described. Fourth will be a brief description of the utility functions that may be needed.

### 1. Human Resources

The first area to be addressed is human resources. This is comprised of two modules. First is the Personnel Management Module that focuses on the information needed to obtain necessary people, and how to assign them once they have arrived. Second is the Training and Qualifications Module that focuses on all the records necessary for the Assistant Maintenance Officer to effectively manage the personnel assigned and their training and qualifications.

#### *a. Personnel Management Module*

An OMA requires a variety of people of various rates (work specialty), paygrades (seniority), and training (skill). The "ideal" mix of people is specified in the Squadron Manning Document (SQMD), which is developed early in the procurement of the aircraft weapon system from the Planned Operating Environment (POE) statement for each activity. The Naval Military Personnel Command (NMPC) assigns real people to each activity to fill the "billets" speci-

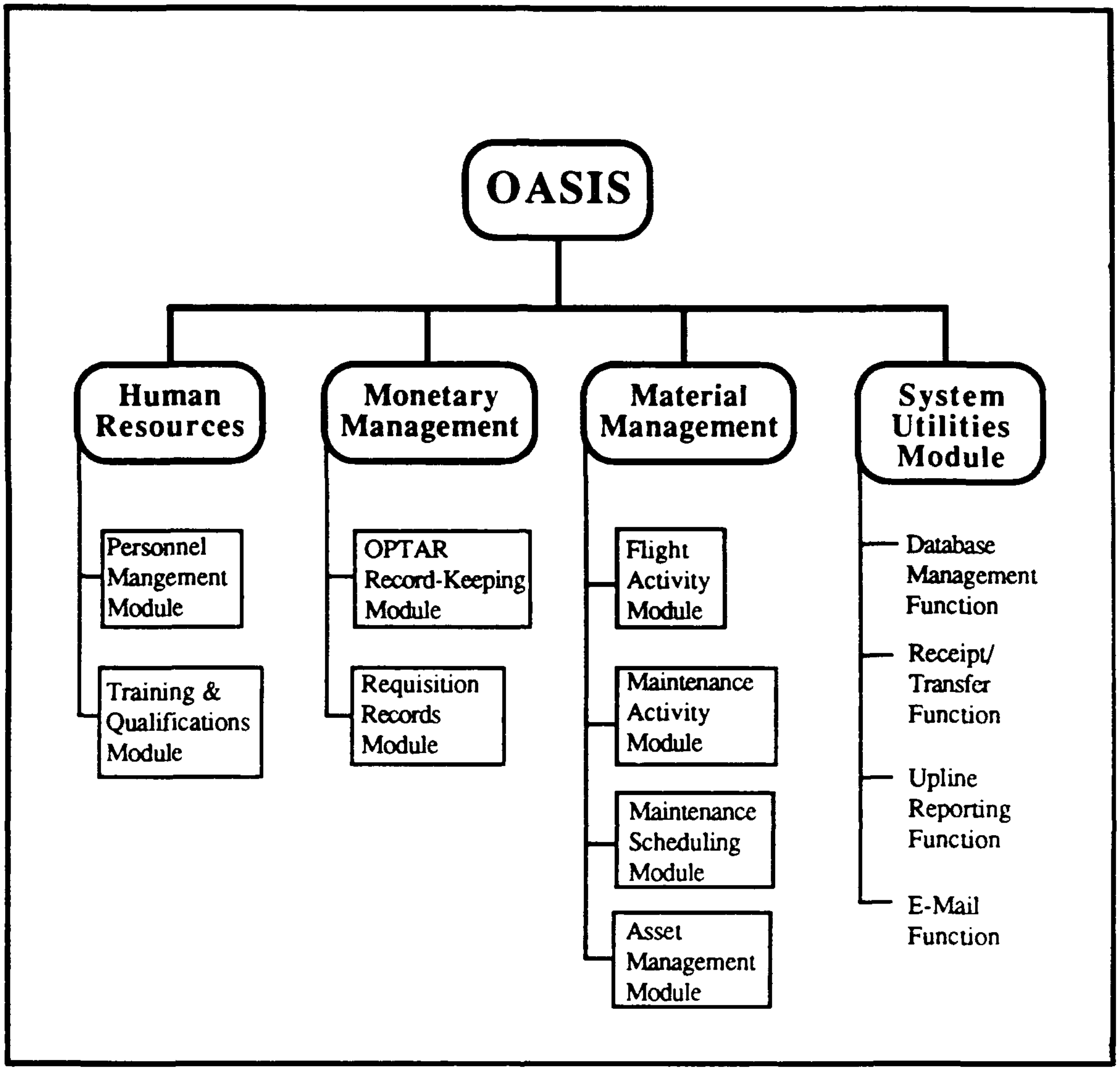


**Figure 5. OASIS Hierarchy of Modules**

fied in the SQMD. Those assignments are made according to priorities that change as supply, demand, and operational commitments change. In a perfect system every activity would have all the people specified in its SQMD. That however is seldom the case. Usually having just the "right" mix of talent and the right number of people requires close liaison between the personnel officer (in

reality, usually the personnel chief) of the activity, the Assistant Maintenance Officer (AMO) of the activity, the next higher personnel office (usually the functional wing), and NMPC. It involves negotiation, detailed knowledge of the assignment system, and most importantly, extensive knowledge of the real skills of the people in the OMA, how long they will be in the OMA, and what the future commitments of the OMA really are. The entire range of knowledge required by the AMO is not gained overnight. To be effective in obtaining the people an OMA needs from the personnel distribution and assignment system requires years of working in the system, OR someone else with those years of experience, i.e., an expert, who can (and will) help and teach you.

Once the people have been obtained from the personnel system and have actually arrived at the OMA, there is the problem of managing specific billet assignments both within the OMA and to various detachments. The initial assignment is usually based on the billet to which the individual was ordered, the individual's past training and qualifications, and the immediate needs of the OMA. Subsequent assignments are based on what the managers have learned about that individual's real skills, and the specific needs of that OMA.

This module is an area where both a decision support system and an expert system could be beneficial. The internal assignment problem is fairly straightforward and may lend itself to a DSS solution based on a set of models with constraints included. The problem of obtaining personnel in the first place may be best solved using expert system techniques. The rules of the personnel assignment system now contained in assorted instructions could be encoded in a knowledge base; the specifics of the activity's personnel assignments would be

contained in a data base; and the knowledge contained in the minds of the experts now in the fleet could be extracted by a knowledge engineer and encoded in the knowledge base as well.[18] Assigning people once they have arrived does not necessarily require an expert system, but in the process of getting them there in the first place an AMO with little knowledge of the Navy personnel system could benefit from expertise leveraged in the form of an expert system. The analogy between maintenance managers and information systems applies again. Maintenance officers are not personnel system experts. Yet they are tasked with using that system to achieve the goals of the OMA. Providing them "expertise" in the form of an expert system could significantly reduce the time they must spend learning the personnel system before they are able to use it effectively to the advantage of their OMA.

#### b. *Training and Qualifications Module*

Within an OMA, two of the Assistant Maintenance Officer responsibilities are to "Establish and coordinate the department training program" and "Obtain school quotas to support training requirements." [Ref. 10: p. 4-10] As with the technology associated with information systems, aircraft technology has also made great advances. Maintaining aircraft is impossible unless people have the appropriate skills. Sources of those skills include Navy training schools, general maintenance training, in-service training, aviation maintenance management teams, and manufacturer's technical representatives. Means of measuring training range from individual testing such as in the Maintenance Training Improve-

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[18] The data base for matching an activity's Manpower Authorization (MPA) to the actual personnel assigned is currently being designed as a thesis project at Naval Postgraduate School [Ref. 52].

ment Program (MTIP), through summaries of training accomplished, to the final measure, sustained aircraft readiness. Closely coupled to training is the need to track various qualifications. Examples include swim qualifications, specific safety training, welding certifications, and other one-time or periodic qualification type requirements. The paperwork documentation required to manage the training effort is tremendous. For example, this author, in one month has had to personally review a 10-20 page report on each of nearly 150 people in his department. All of that information is already in electronic form; in fact the reports were printouts from the Aviation Training Support System--Phase II (ATSS-II) system. Therefore, the training module of OASIS should provide a transparent interface to training records that are already kept electronically in ATSS.

A micro computer-based system to manage and track the training requirements listed above was under development at NAS Miramar in 1987-1988. When the author left *Fighter Squadron Twenty-One* (VF-21) in 1988, this system was in use at VF-21, VF-154, and AIMD Miramar. It or a similar system could be used as the basis for the module to help AMOs manage training.

### 2. Monetary Management

The second area to be addressed is monetary management. This is comprised of two modules. First is the OPTAR Record-keeping Module that focuses on the information needed to manage the funds OMAs are authorized to obligate. Second is the Requisition Records Module that focuses on the records necessary to keep track of all the items ordered and received by the OMA.

#### a. *OPTAR Record-keeping Module*

OMAs are required to keep a record of all funds they have been authorized to obligate and of those obligations. These records are usually kept manually in the OPTAR log (NAVCOMPT 2155). The specific detailed instruction for correctly maintaining the OPTAR log are found in Navy Staff Office (NAVSO) Publications 3006 and 3013 [Ref. 10: p. 6-136]. If those requirements were automated then much of the time spent finding and correcting errors, usually simple arithmetic errors, and balancing the OMA's records with those of the "official" records of the Fleet Accounting and Disbursing Center (FAADC) could be reduced. Processing the transmittals (NAVCOMPT 2156), Summary Filled Order/Expenditure Difference Listings (SFO/EDLs), and monthly Budget OPTAR Reports (BOR) could be streamlined and made more accurate by automating the necessary procedures. Once the data is in electronic form, additional potential benefits include correcting errors at the point of entry, automatic upline reporting, and the ability to present the data in a variety of formats, even pictures, i.e., graphs, for upper level management (usually not experts in the subject). At least two activities the author is familiar with are using a simple spreadsheet package to accomplish this now. The problem with their applications is that they were developed by people who have since left the activity. Now, when problems occur (and they will), or changes are required (and they will be), these activities will either revert to the manual way of record-keeping or will find someone who can spend the time learning the application and correcting the problem or making the change.

#### *b. Requisition Records Module*

NALCOMIS Phase II includes a terminal for most OMAs that links them to their local supply activity. This has proven of great value to maintenance managers. It is used to order parts, to inquire about status of previously ordered parts, and to verify in or out of stock situations. Stock information is critical to a maintainer. If the part is essential, one of the alternatives for obtaining the part (if it is not available from supply) is to take it out of an otherwise not flyable aircraft. "Cannibalizing," as this process is called, requires double the normal maintenance effort. Instead of removing and installing one component, two are removed and installed. Three components are now exposed to potential damage from the removal and installation process, rather than the two had cannibalization not been necessary. By knowing the component is "on-the-shelf" and "ready-for-issue" (RFI), a maintenance manager can minimize unnecessary cannibalization actions. OASIS, either through NALCOMIS Phase II or other means, will provide a means of obtaining this information.

An additional benefit of obtaining such parts information is the possibility of maintaining an automated requisition logbook. As part of the ordering process, where component information is already available electronically (through NALCOMIS Phase II), capturing that information and loading it into a local OMA data base would be of great benefit. Part numbers, stock numbers, item description, and time ordered are the type of data that would no longer have to be re-entered every time an item is ordered. The hand-scribed (and sometimes illegible) logbook now required could be replaced by a clearly readable and unforgetting automatic one.

### 3. Material Management

The third area to be addressed is material management. This is comprised of four modules. First is the Flight Activity Module that focuses on recording and using information about flights. Second is the Maintenance Activity Module that does the same for maintenance actions. Third is the Maintenance Scheduling Module that addresses determining the optimum schedule for completing repairs. Fourth is Asset Management Module that addresses the inventory management of OMA assets.

#### a. *Flight Activity Module*

This module collects the raw data, specifically flight hours, used to maintain the logbooks of aeronautical equipment. One of the functions of this module of OASIS will be to provide an automated logbook. Current procedures require many calculations to properly remove and install equipment in an aircraft, and once installed, to account for the operating time of that equipment. By automating those procedures, many of the hours this author has witnessed (and spent) finding simple arithmetic errors can be avoided. Additionally, since the data is kept electronically, the only time a paper copy would be needed would be when the equipment is transferred, or when signatures are required. That paper copy could, at least for now, be an exact replica of the logbook forms currently used. This could change in the future should the need for the paper form be removed. This module would be used to provide MCCs with up-to-the minute status of any of the aircraft under their care.

Flight hours accrued by a component are one of the ways of determining when to perform scheduled maintenance of aeronautical equipment.

Collecting that information as it occurs has a significant impact on even simple maintenance actions like an oil sample that may be due every ten hours of operation. Most OMAs have devised some way of keeping the MCCs aware of which components are coming due for a particular preventative maintenance action. The terms "Time since new sheet", and "Time sheet" are used to describe these end-user developed information systems. Some are automated, and some are still manual. All provide MCCs with a single sheet containing the time remaining until the next required preventive maintenance action[19].

Configuration accounting is one of the functions of aeronautical equipment logbooks. Accordingly that function should be performed by the module that contains the automatic logbook. The data necessary to maintain an accurate configuration for all equipment will come from the VIDS MAF data representing technical directive compliance when that data is collected in the Maintenance Activity Module (discussed in "b. Maintenance Activity Module" on page 75). As parts are removed and replaced on aircraft or other aeronautical equipment, the data entered to record those actions would automatically update the configuration records for the equipment.

The computer aided NAVFLIR data entry system (CANDES) is a micro computer-based system that performs the flight data collection function, but with the intention of providing the NAVFLIR data into an electronic form

19 Some of these sheets present the information on an accruing time basis. What is printed is the amount of time since the previous maintenance action occurred. This means that the MCC must perform some arithmetic to arrive at the "due" time of the next action. Another type counts down to zero. The times listed on the time sheet are the amount of time remaining until the specified action must be performed. Most of these reports are produced once a day, and the MCC performs simple arithmetic through the day to update the figures on his sheet.

to Data Services Facilities (DSFs) to upload into the AV-3M system. CANDES was born in the spring of 1989 and first tested in November 1989 [Refs. 53 and 54]. At last report [Ref. 54], it is a success at all sites where it has been fielded, and plans to install it at additional sites[20] are being implemented. CANDES could be expanded to fulfill other flight hour related or dependent functions and become the Flight Activity Module of OASIS.

#### *b. Maintenance Activity Module*

The maintenance history of aircraft, both an individual aircraft, and an entire type, model, series (TMS) of aircraft, can be very valuable to maintainers. If there is a sufficient history of equipment failure, then future failures can be predicted with a specified level of confidence. If MCCs had access to such data they could make better educated decisions about the likelihood of a particular part being the cause of the current problem facing them. Another use of historical data is planning which parts and how many of each to take on a detachment. If two widgets fail every week, and the detachment is one week, then taking two widgets would be appropriate. The same parts usage data is used by procurement activities to decide how many of each part to buy for a given period of time. The means to obtain historical data must be part of this module. Current data must be collected as it is generated by current maintenance actions. Additionally, historical data may be available from the AV-3M or NALDA sys-

20 At this writing, which Navy activity will be the configuration manager and who will provide post deployment systems support for CANDES has not been decided. This means that when (and if) CANDES transitions from the Naval Aviation Maintenance Support Office (NAMSO) prototype to an implemented system, there may be no support.

tems. A user-transparent retrieval of historical data from those systems is essential.

Collection of data about maintenance actions as they occur must be a priority. Each aircraft has its own "personality", or failure tendencies, and quick access to data about an aircraft's past failures can sometimes give indications about current problems. Additionally, monitoring trends, now done laboriously by quality assurance personnel reviewing individual VIDS MAFs, could be automated. Some pre-defined trends could be tracked on a regular basis, such as how many reported failures could not be duplicated during troubleshooting. Other trends could be provided on an ad hoc basis.

Once the data is in electronic form, it can also be used to satisfy upline reporting requirements. Readiness statistics in the form of mission capable and full mission capable figures could be calculated automatically in accordance with both the NAMP and AV-3M system which monitors the full twenty-four hour per day capability, and the Aircraft Material Readiness Report (AMRR) which provides a "snapshot" of aircraft status (typically at the start of daily flight operations).

One of the forms used to collect data is the VIDS MAF. It contains over 50 blocks of different data elements, with over 200 spaces for data. The VIDS MAF has been limited to one page for years in an effort to minimize the paperwork as well as to not overwhelm those who must fill in the forms. To that end, associated with each block is a set of codes used to describe the maintenance action that occurred [Ref. 45: p. 6-11]. If we go to a computerized version of data

collection, the arguments for one page become less compelling[21]. The ease with which windowing[22] is used in today's technology would allow the presentation to the user of only that information required at that particular stage in the maintenance action documentation process. The necessary codes could be displayed on demand. Another option would let the user pick the correct code from a list on the video terminal screen, thereby eliminating most of the guessing, typing, and transcription errors. A computerized version of the VIDS/MAF would also allow more descriptive information in the write up of the actual problem. The point is that even though more complete and accurate data could be collected, each user would have to deal only with that portion of the data that applied to him/her.

We may not be able to do away with paper entirely, since there will remain the need for signatures at some points of the maintenance cycle. That signature requirement could be satisfied if we had the data collection system print the signature part of the VIDS/MAF whenever someone must actually affix his/her signature. There may be other alternatives to signatures, and these need to be considered and evaluated. If weaning maintainers from their VIDS board proves too difficult[23], then have OASIS print a form (which could be adapted to the preferences of the specific OMA) for the VIDS board--just do the data entry at a terminal and get the data at the source. Benefits of automation include more

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21 This does not imply that we should collect more data, only that we can now use a single screen display for each step in the maintenance process, and that the one page limit should be re-evaluated in light of using computerized data entry versus a paper form.

22 "Windowing" refers to the ability to overlay a second (or more) screen of information, even including the running of another application, on top of the one currently in use.

23 After an unbiased comparative analysis of both the VID system and the computer based system, we may find that the VIDS has advantages we are unwilling to give up. Two such advantages are that it is not subject to electrical power failures and that it is already well known and understood throughout the fleet.

accurate data: maintainers won't be "remembering" which code to use in which block, but will be able to pick the right one from a list in front of them. No more legibility problems at the DSF, no more typographical problems, at least within the allowable characters for a given block, and fewer keypunch errors are all likely results of collecting data in electronic form.

#### c. *Maintenance Scheduling Module*

An expert system to assist Maintenance Control Chiefs in allocating their scarce resources optimally among all the competing short, medium, and long term objectives would be the key element of this module. Such an expert system was found to be feasible by McCaffrey in 1985 [Ref. 6: p. 122]. As previously discussed, the supply of true experts in the field of maintenance is below the demand, so the need to leverage those we do have is great. Even though expert systems have reached the commercial market since McCaffrey's work in 1985, their use by DOD the operating activities is low or non-existent. Therefore, a particularly productive project for the Navy's graduate students at the Navy Postgraduate School would be to apply ES techniques to helping all maintenance chiefs be more effective. The first part of the problem to be addressed should be something readily definable, such as some of the scheduled maintenance requirements. Later iterations could add other aspects, un-scheduled maintenance, for example. In that way, OMAs could benefit from having a "consistent" expert available at any time.

#### d. *Asset Management Module*

Although assigned to the material control work center (except for publications), these functions cross all work center, division, and department

boundaries and are therefore grouped into the one module. In effect this is an automated inventory system for all OMA assets. Keeping track of all an OMA's assets is a very time-consuming repetitive task that requires meticulous attention to detail Such tasks are ideally suited to automated record-keeping. OMA assets include everything from janitorial equipment and office supplies to expensive test equipment and computers. The technical publications library, which includes all the repair manuals as well as Naval instructions, is included as are IMRL equipment and common hand tools.

The tool control program requires positive accountability of all tools lest they find their way into the wrong place and do damage (known as foreign object damage or FOD). To achieve such accountability, accurate and detailed inventory records of every tool are imperative. The tool boxes for these tools are arranged with some means of visually ascertaining in just a few seconds that every tool that belongs in tha container is there or that its location is known. A future enhancement to this module, as technology inexorably advances, would be to add the shadow diagrams for every tool box to the automated inventory records. This would allow the tool control plan for each aircraft to be distributed electronically, rather than on paper.

The master inventory of the activity's aircraft would also be kept by this module. Flight packets would be accounted for and even "signed" for by pilots through this module as they signed for their aircraft. When the technical publications library is distributed via Compact Disk-Read Only Memory (CD-ROM), the ease with which MCCs could search for and find the obscure detail about a component, procedure, or requirement would be greatly enhanced.

## 4. System Utilities Module

This module will perform a number of diverse functions common to the other modules. The list is not exhaustive: in fact, other general utility functions will undoubtedly be desired by the end-users. The minimum starting set of functions is described in the following sections.

### *a. Receipt and Transfer*

Receipt and transfer of equipment would be a function of this module. Any time an item was received, data from its logbook would electronically be added to the OMA's inventory via this module. Upon transfer; just the reverse would occur. Any necessary paper copies would first be printed and then the electronic logbook would be transferred, either directly via communications link or by diskette. This process would apply to aircraft in particular but also to all other aeronautical equipment, particularly support equipment and IMRL.

### *b. Communications*

A telecommunication system would connect all parts of the system. The interfaces to other systems would be transparent to the user because of standard interface programs contained in this module. Also included would be an electronic mail (E-Mail) system. This would operate on what would effectively be a local area network (LAN) within the OMA. The telecommunications capability would allow readiness reports, for example, to be prepared by the analyst, reviewed by the Quality Assurance Officer, the Assistant Maintenance Officer (AMO), the Maintenance Officer (MO), the Operations Officer (OPSO), the Executive Officer (XO), and the Commanding Officer (CO) and then to be sent to higher authority without ever being produced on paper.

#### c. *Database Management and Maintenance*

All database management and maintenance functions would be performed by this module also. Periodic backup of the OMAs database would be automatic. Any batch processing such as periodic standard reports would be handled within this module. In effect, this module would be the "traffic cop" for data flow within OASIS. The precedence procedures to prevent two people from trying to change the same data element at exactly the same time would be encoded here. The database management system must include the capability to support a wide array of ad hoc queries. A minimum requirement is including the standard query language (SQL).

### 5. Summary

The module descriptions presented represent the conceptual organization of OASIS. It should be readily apparent that developing a single system to perform all these functions is a demanding task. In fact, it is simply too big and too complex to accomplish in one system development effort, as the history of NALCOMIS shows. A project of this size will take too long and will make keeping up with changes even more difficult during development because the longer the development time, the more changes are likely to occur. Such an effort, trying to develop and deliver everything all at one time, is, however well-intentioned, doomed to fail.

## D. IMPLEMENTATION PLAN

This section will address some general systems implementation issues as they relate specifically to OASIS, and then outline the preliminary OASIS implementation plan. The plan is only preliminary, since it will need to be in much greater

detail than possible here. Additionally, the plan, once formalized will be subject to frequent change. Another factor is that information systems planning has advanced so far technologically that even the strategic planning process is now automated. At least the documenting of the process and resulting plans is automated. (We haven't automated thinking yet). The value of such automated tools is significant particularly to a project such as OASIS which is intended to evolve and change as each module is added and as the operating environment changes. Automating the record-keeping, documenting and plan generating will both ease the administrative burden and reduce the potential for overlooking something when making changes to the project specifications and plans. Those who actually develop OASIS should take advantage of the automated development tools available today.

### 1. Related Issues

There are several issues related to the development of any information system for aviation maintenance. They include identifying the customers of the system, deciding whether to develop the system in-house or contract for the development, developing a data dictionary/directory, deciding which hardware and software to use, identifying and specifying interface requirements, identifying potential applications for expert systems, deciding whether to follow a traditional or prototyping approach, performing a cost-benefit analysis of the project, and evaluating previously proposed systems for inclusion in OASIS.

#### *a. OASIS Customers*

Many people in aviation maintenance need information about readiness. If OASIS is to satisfy their needs, identifying those customers explicitly is

essential. To any organization, customers fall into two groups, internal and external. Internally, the customers of OASIS are the professional maintenance managers who have spent years learning their profession, the Maintenance Control Chiefs, and professional maintenance officers. Other beneficiaries include aviators assigned as Maintenance Officers and Division Officers, the quality assurance division, and material control and maintenance administration work centers. By virtue of the benefits accrued by those professional maintenance managers, the whole activity will benefit from better overall performance and readiness. None of these users will really care what the system is called or how they got it, as long as it helps them do a better job.

Externally, the customers of OASIS are all the other systems with which it must interact and those higher authorities to which the OMA provide both raw and summarized data. Some of these have already been identified, but an exhaustive list should be prepared that includes a detailed description of the technical hardware and software interface requirements for each.

***b. In-house Development versus Out-house Development***

The question as to whether OASIS should be developed within the Navy or outside the Navy by a contractor, must be thoroughly analyzed and finally decided. There are benefits to both. By doing the development in-house, we have control of the entire system development, do not have to learn the aviation maintenance business, and do not have to worry about a contractor not going to sea to maintain the system he just delivered. On the other hand, we must maintain the information systems expertise to develop, implement, and support the system after deployment. In this era of fewer funds, doing the development

with people who are already "on staff" avoids the cost of hiring new people. However, those same "on staff" people must devote time to system development that they would normally devote to other duties. The real impact and cost of both options needs to be investigated. One of the things strongly favoring in-house development is the growth of end-user development.

*(1) Managed End-user Development.* End-users (the internal customers) have little or no idea of what can be done with current information systems. They are aircraft maintainers, not information system developers. What is needed is to somehow expose them to the possibilities. The best way to do that is to provide them something they can use, i.e., something that will help them do their jobs, while at the same time sparking their imagination about other functions an IS can help them accomplish more effectively. Those ideas can then be incorporated in the next release of OASIS. This procedure is much the same as followed by marketers of major software products, and is also part of the philosophy advocated by Total Quality Management, i.e., continual improvement.

For the same reason, i.e., end-users have little or no idea of what can be done with current IS technology, to expect them to be able to define their requirements at the very beginning of a project in a manner from which an IS could be developed is expecting too much. To do so is to invite the chance of missing out on an opportunity to take advantage of 1) software and hardware technology advances that occur during a long development, and 2) end-users' imaginations that can be stirred by having a sample, i.e., a prototype. Therefore, an effort to manage the end-users' developed applications in conjunction with OASIS prototypes is essential. In reality, some of the end-user's applications may

very well form the beginning of OASIS modules, if not becoming the modules themselves.

*(2) NAMO's Functions.* The Naval Aviation Maintenance Office (NAMO) has several responsibilities specified in the NAMP. Among them are "Developing and maintaining management information systems which directly support the fleet," and "Planning, design, development, implementation, and support of all information systems/decision support systems which support the total life cycle of aeronautical equipment." [Ref. 9: p. 4-4] These responsibilities are effectively a charter for NAMO to bring all fleet aviation maintenance and support information systems under NAMO's purview.

(a) Central Design Activity— In accordance with its NAMP charter, NAMO should be the Central Design Activity (CDA) for all aviation maintenance information systems, from the Naval Aviation Logistics Data Analysis system (NALDA) and the AV-3M to OASIS. As CDA, NAMO would have the unique opportunity of being the keepers of both the NAMP and the information systems that support the NAMP. In other words, the maintenance experts who manage the NAMP would have the same chain of command as the information professionals who provide the information systems for the NAMP. As two different groups of professionals with the same goal, i.e., support to the fleet, such a relationship can have only synergic benefits. The parallel to the relationship between aviation maintenance and aviation supply is inescapable. The maintenance supply relationship resulted in the Joint Aviation Supply Maintenance Material Management school being developed. It is time for a

similar relationship between experts in maintenance and experts in information systems to be established.

(b) Configuration Management— NAMO can and should, under the authority of its charter, act as a clearinghouse and configuration manager for end-user developed applications. Of particular interest are those that are not (yet) part of OASIS, but that might be of benefit to OMAs other than the one that developed the application. In response to a request from NAMO, an OMA would send NAMO a copy of their application. NAMO would be responsible for verifying that it complied with the NAMP and other applicable instructions and standards. NAMO would then make any changes deemed necessary, e.g., superimpose a standard user interface. Finally, NAMO would make a compiled version[24] available to all other OMAs either by electronic bulletin board, or by mailing diskettes. The original developer would submit preliminary support (both user and maintenance) documentation in electronic form, which NAMO would update as it updated the code and subsequently provide to all users as part of the product. This whole process should occur electronically. Because of the volume and variety of the end-user applications, NAMO would have to filter the responses. In other words, if 25 applications to automate the logbook were received, NAMO would choose or combine features from different applications into a single version of the automated logbook which would then be supported by NAMO. (NAMO may not provide the actual post deployment software support, but would coordinate, as the configuration man-

24 A compiled version is one that has been reduced to actual machine instructions, and is no longer in the original programming language (called the source code).

ager, the PDSS efforts. The actual support may be provided by Navy software activities, NPS, or contractors.) The availability of these application programs should then be made known to all OMAs. This could be initially done via Naval message, with subsequent follow-up articles and listings in professional aviation maintenance magazines such as *MECH* and *CROSSFEED*. Even possible, but unlikely in view of expected funding limits, is that a separate publication could be started to advertise the applications available as well as to provide articles of general interest to aviation maintenance computerized information systems users. At the very least, an electronic bulletin board should contain, if not the actual programs and documentation, a list of what is available and how to get them.

*(3) Participation.* NAMO should solicit users' input as to the first module to be developed. Those who should be consulted include the OMAs (the end-users), Type Commanders, Fleet Commanders, the Aviation Maintenance Officer School, and the current NALCOMIS office (PMA-270). Once the first module has been selected, developed and fielded, the next one should be chosen and the process repeated. As each module is developed and feedback is received from the end-users, priorities may actually change from those proposed in the preliminary implementation plan. If that is the case, fine. There is nothing sacred about the preliminary implementation plan for OASIS.

***c. Data Dictionary/Directory System***

A simple but potentially very time-consuming issue is that of the specific data elements an activity (and OASIS) will use. For example, a decision is necessary as to whether a social security number is nine digits separated by hyphens, nine consecutive digits, or some other arrangement of digits and symbols.

Another example is the format for a date. There are dozens of variations, from day month year, to a four or five digit Julian date. The MDS Validation Specifications [Ref. 55], also known as the VALSPECS should be used to establish the initial data dictionary. As applications are developed, a data directory should be added so that the impact of changes proposed in the future could be assessed, as well as ensuring that those changes actually made are complete. Once the initial DD/DS is established from the VALSPECS, the systems with which OASIS must interact should be assessed to 1) determine what if any differences exist, and 2) build standard conversion modules to make data transfer among them transparent to the end-users.

#### *d. The Hardware-Software Decision*

Deciding which specific software and hardware OASIS will use should be left until as late as possible in the development cycle. Initially, for the prototypes, existing hardware and software could be made to suffice. Only when OASIS approaches full functionality should the decision about hardware and software be finalized. That way, the latest advances in both technologies can be made a part of OASIS. Of course, since the micro computers of today have the capability of mainframes and mini computers of 15 years ago, assuming that OASIS will be based on a micro computer is a safe and logical assumption. The specific make, model and capabilities should be left until a better understanding of the functional and technical requirements is obtained through the development of the first few modules. This of course implies that the first few modules will be required to work on the hardware and software already available at most OMAs.

The question of which software package or combination of packages to use to develop OASIS must also be answered. This issue will have to include a decision as whether or not to standardize on one language (such as ADA) for all of OASIS development. Many application packages are available, from basic spreadsheet and database packages to more advanced and sophisticated fourth generation languages. These packages were designed to perform the same type of functions needed in some OASIS modules. Using them may reap the benefit of easy development, but may also incur the threat of poor or no support at some time in the future. ADA on the other hand, is the DOD directed standard language and therefore we have some assurance of long term support. However, using ADA would involve considerably more effort than using commercially available software application packages. It would also mean that all the applications already developed and in use would have to be re-written. Whatever decision is made will have long term implications for both development and post deployment support and maintenance of the system. This decision should not be made lightly, and in fact may require a study of its own.

***e. Interface Requirements***

The need for OASIS to interact with other information systems must be recognized from the outset. NALCOMIS Phase II, SUADPS, UADPS and NALDA are four of those for which an interface must be developed. Since they most likely have different technical and logical requirements for interaction, each of them must be investigated and the interface requirements specified. This will involve such things as the format and order of specific data elements, as well as the technical specifications such as transfer rate. Once those requirements are

known, standard modules should be developed to be included with OASIS modules sent to an OMA that must interact with any of those systems. For example, to link to NALCOMIS Phase II will require that the data conform to the VALSPECS, but also data transfer protocol must be specified. These are technical details beyond the scope of this thesis, but they must be resolved for OASIS to reach its full usefulness to OMAs.

#### *f. Expert Systems*

All the fault isolation in the world will not fix the fault. Once a piece of equipment has failed, and the fault has been isolated, the real problem of allocating resources to repair it begins. Resource allocation necessitates consideration of the OMA's goals and missions. Short term goals like today's flight schedule, medium term goals like next month's detachment to NAS Wherever, and long term goals such as the next deployment should all have an impact on the allocation of resources.

Expert systems hold significant potential to assist in several areas of aviation maintenance and particularly that of resource allocation. Resource allocation is essentially what MCCs do. They consider the resources available to them, e.g., time, people, funds, equipment and tools, compare those resources to their goals, and formulate a plan to achieve those goals. Leveraging the expertise of the most experienced maintenance chiefs for each type of aircraft has tremendous possibilities. The job of MC is just too complex. It requires too much specific knowledge in too many areas for one person to be able to manage it all. This has been recognized by the division of responsibilities into material control, maintenance control, and maintenance administration, but even these divisions

are becoming inadequate as managers are overloaded with programs, data, & requirements. Most MCCs rely on other subject matter "experts" to help them when they need information about a specific area. This is to aid them in making decisions. What happens when such expertise is not available EXACTLY when it's needed? You 'punt' as it's commonly called, or make a wild guess. In academic parlance you satisfice--pick the best guess you can and make do with it. Alternatively, you wait until the expert is available, which has all the potential drawbacks associated with a delayed decision, such as missing a launch or launching late.

How can this problem be solved? Find a way to make the expert available to all who need the knowledge anytime they might need it. The cost of doing this with people, just in the sheer numbers, not to mention the cost of training and retaining, is obviously prohibitive. Furthermore, based on past experience, in spite of the best intentions in attempting to accomplish this desirable objective, we have not been 100 percent successful. In other words, some OMAs still lack the required expert. An alternative is to leverage the experts we do have in such a manner that they do not need to be there, on site, or even available by phone. Here is where an ES can help. Expert systems are the means to leverage our experts.

Several questions will have to be answered for any expert system incorporated within OASIS. They include:

- Who will champion the project? In other words, who (or what office) will undertake to convince the people with funding to support development of an expert system?
- Who will be the knowledge engineers? Who will translate the experts' knowledge into an expert system?

- The knowledge engineers will likely not be in sufficient quantity to gather all the knowledge from the maintenance experts. Who will serve as apprentice knowledge engineers, helping the knowledge engineers, and in the process become knowledge engineers themselves?
- Who will be the maintenance experts from whom the knowledge is gathered? Will they be available? Can they be convinced of the need for an expert system, and thereby lend their full support? Will their bosses allow them to work on an ES development project that may detract from their performance of their normal duties?
- Are the existing (or planned) databases sufficient for the needs of the ES, or will they have to be developed also?
- Who will keep the database(s) in the ES up-to-date?
- Who will provide the post deployment support for the ES?
- Who will keep the knowledge base up-to-date?
- Who will decide what knowledge will be included, and when changes to that knowledge base are appropriate?

An ES will require as part of its database, the maintenance history of each aircraft. Whether this history is down-loaded from the AV-3M system, or extracted from the Naval Aviation Logistics Data Analysis (NALDA) system, or is collected on site in a local database as part of the Maintenance Activity Module, needs to be determined. An expert system can resolve uncertainty in one of two ways. Either the needed probabilities are encoded in the knowledge base or the ES extracts data from the database and calculates the probabilities as needed. Since the Maintenance Activity Module and the Flight Activity Module will hold much of the data the ES will need, they will have to be developed before or concurrent with the ES.

#### *g. Traditional Development versus Prototyping*

*(1) Traditional Development.* The traditional systems development life cycle as presented by Whitten, Bentley and Ho is a "generalized problem-solving approach...[that has]...eight steps or phases:

1. Survey the situation.
2. Study the current system.
3. Define user requirements.
4. Evaluate alternative solutions.
5. Select new computer equipment and software (if necessary).
6. Design the system.
7. Construct the system.
8. Deliver the new system." [Ref. 13: pp. 142-155]

Note that this approach, in contrast to the information engineering (IE) approach described earlier, places emphasis on the current situation and systems first. (IE on the other hand, eschews deriving the new system from the old in favor of emphasizing the organization's information needs.) With this approach the end-users are mentioned or implied only twice, when defining their requirements and when delivering the system. One of the techniques used in the traditional approach to help define user requirements has been a prototype.

*(2) Prototyping.* The best way to get user input is to let users see what is possible. Providing them a quick and dirty prototype that shows them what is available would generate discussions about real requirements and nice-to-have requirements and would likely provide meaningful user input. This will also get people thinking about possibilities. Providing a prototype of OASIS to all 400 plus OMAs is obviously prohibitive. However, a single one could be taken

to the major Naval Air Stations for demonstration and comment. The Wing (TYCOM) Maintenance Officer can host conferences of MCCs and MMCOs to present the idea and solicit input/feedback. Using a prototype to define and refine requirements is the best development method to use. A prototype is a relatively inexpensive way to make sure the early planning is correct, and thereby avoid some of the problems that have plagued other projects in their later stages.

Another particularly telling point about end-users and prototyping should be made. The end-user is an expert in his field, not information systems or information systems development. By asking them what they want, we can expect only some generalities. So, we should take those generalities (since they are all we can get) build a prototype of what we think they want, and give it to them to use and critique. As their needs begin to crystallize, so will the information system to satisfy those needs.

Turban [Ref. 22: p. 150] differentiates between two types of prototypes, *throwaway* and *evolutionary*.

*(3) Throwaway Prototypes.* The *throwaway* prototype is built and used once. Its purpose is to get information from the users about the system they really envision. Once the requisite amount of information has been collected, the prototype is discarded. As Brooks says,

> The management question, therefore, is not *whether* to build a pilot system and throw it away. You *will* do that. The only question is whether to plan in advance to build a throwaway, or to promise to deliver the throwaway to customers. Seen this way, the answer is much clearer. Delivering the throwaway to customers buys time, but it does so only at the cost of agony for the user, distraction for the builders while they do the redesign, and a bad reputation for the product that the best redesign will find hard to live down.
> Hence *plan to throw one away; you will, anyhow.* [Ref. 44: p. 116]

*(4) Evolutionary Prototypes.* Another approach to prototyping is called *evolutionary* [Ref. 22: pp. 150-152]. This is where a prototype is built to perform what are thought to be the most important functions and given to the user to use and critique. Based on the user's critiques, the prototype is changed and returned to the user. This process of continually improving the system is repeated until the users agree that they have what they want. Then the system is integrated with others to form the "final" system[25].

An additional benefit to this approach is that as we attempt to put what they want, and how they do business, into a system we (and they) may find that the process they are currently using really does not work the way they think it does and needs to be changed. Commensurate with re-thinking the current process, is the need for the system itself to be flexible enough to accommodate the changes in the process that may come to light during development.

*(5) Pre-Prototype Survey.* Before building a prototype the users must still be consulted about what they would like the system to do for them. Since the OMAs are so geographically dispersed (literally around the world) travelling to each of them to personally gather their responses would be prohibitive. Therefore another way to get the initial desires must be used. A survey of all the OMAs, by Naval message or letter would provide a starting point for building the prototype. There are a variety of questions that could be asked in such a pre-prototype survey. They include:

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[25] In terms of the entire life cycle of the system, using the term final is incorrect, since there will in fact be alterations. However, final is often used to refer to the version of the system that did or will exist when the system reaches a particular milestone in its life. That version is the final version of that phase of the system's life cycle.

- What decisions need the most support, or are the most difficult and require consulting an expert? (The goal of this question is to find out by simply counting the votes, which areas of maintenance would benefit most from an expert system.)

- What would the MCCs would like to see automated? (This question is a wide open one, and may need to have a few examples to prompt answers. The level of response and specific answers could be used to assign priorities to the different modules of OASIS, expert systems included.)

- How much and what type of support and training would they like. (Again examples would be useful to prompt responses, but this could be used to assess the level of post deployment support they expect.)

- What is the opinion of upper management, specifically the CO and XO with regard to the ability, experience and performance of their maintenance organization? (This question will provide a view of the "real" quality of the experts out there, and may also help identify those maintenance professionals who should be tasked with being "experts" for the development of the system.)

- Do COs, XOs, OPSOs, and MOs get the information they when they need it and do they have confidence in it? (This question accomplishes two goals if answered. First, the response will provide a measure of the "climate" into which we intend to place OASIS, i.e., how receptive the commands are to computers and automation. Second, it will provide us with a measure of what upper managers think is important. They too are customers of OASIS, expert system included, and if we build those modules that respond to both upper management and the MCCs, acceptance of the system will be greater.)

- A question that could be asked of COs only is whether or not they would like to have more and possibly better "expert" help on call, WITHOUT the 'stigma' of asking for help and hanging their 'dirty laundry' out? (This question is another one to assess the perceived need for more quality maintenance professionals.)

- What information is of most value to maintenance control chiefs, and do they get it when they need it, in a form they can use? (This would give an indication of which modules to build first, and which interfaces should be developed first.)

- What equipment do the OMAs have now? This will involve an inventory of the hardware and software currently held at each OMA. (This question would provide an indication of potential prototype sites, as well as an indication of the additional equipment that will be needed to implement OASIS at each site.)

#### h. Cost-Benefit

This project must eventually graduate from research project to deployed system. To do so it will have to be justified and funded. Therefore, NAMO, or whichever activity sponsors OASIS, will have to begin including OASIS in its budgeting process soon. In addition, a detailed cost-benefit analysis will have to be done. Rather than wait until the last minute and try to remember what various costs have been so that future costs can be predicted, do one now and kept it updated as the project progresses. Several methods of cost-benefit analysis are available. Payback analysis, return-on-investment analysis, and present value analysis are just three [Ref 13: pp. 796-802]. The best of these is present value analysis: the other two have limitations. The *de facto* guide in the Navy is *Economic Analysis Procedures for ADP* [Ref. 56]. It provides very explicit "how-to" guidance for performing economic analysis of ADP systems.

Some of the potential benefits of OASIS include increased readiness, more timely and accurate readiness figures, and better maintenance decisions at operating levels resulting in less waste, more effective parts usage, and fewer repairs being made by black box changing vice true troubleshooting. Though difficult to quantify, a reasonable attempt must be made. Estimating what an additional one percent improvement in readiness costs will likely be necessary to help higher authorities determine the costs of increased readiness that will result from implementing OASIS. Costs are much easier to identify and include the obvious direct costs of hardware and software, as well as some not so obvious ones such as supplies, telephone calls, and postage that will be used during development.

Allen and McSwain recommended value analysis be used to evaluate a DSS/ES [Ref. 7: pp 87-88]. Value analysis focuses on the minimum benefits to be achieved by a system in order to be considered successful. Next the maximum amount the user is willing to pay for each benefit is determined. Assuming that the costs are within limits, a prototype is then built. The value analysis process can be looked at as formalized intuition, but is still less rigorous than the cost/benefit techniques listed above. [Ref. 20: pp. 165-167]

#### *i. Additional Systems*

Proposals have been advanced to develop systems that would address various areas of aircraft maintenance management, but none of them has yet been implemented. Several of them are: Aviation Squadron Enlisted Training System (ASETS) [Ref. 57]; an expert system for assigning personnel to squadron detachments [Ref. 33]; an expert system for scheduling maintenance actions [Ref. 6]; a decision support system/expert system for maintenance controls [Ref. 7]; and a system now being proposed as a thesis project at Naval Postgraduate School for matching an activity's Manpower Authorization (MPA) to the actual personnel on board [Ref. 52].

### 2. Preliminary Plan

If we apply the information engineering methodology to the OMA "business" we will find a pyramid with many small projects at the base. All of these can be developed under the umbrella of OASIS. This is when the crucial step is taken. As Mr. Finkelstein advocated in his presentation in June 1989, assign a priority to each of the small projects, and concentrate effort on developing those small projects from start to finish, progressing from one project to the next in or-

der of the assigned priorities The highest priority should be given to those modules that have been identified by the end-users, or those deemed by higher authority to have the greatest impact on accomplishment of the OMA's strategic goals. (Or, if necessary, the projects that will have the greatest visibility with the people controlling the funding.)

One of the benefits of developing a modular plan to satisfy the functional requirements of an information system is that any module can be developed independently of the others. Although a more detailed data analysis is still required, the module organization presented here is based on data dependencies. The only module that may be dependent on another is one using ES techniques that require that a database be developed first (or at least concurrently). Such is the case with the proposed expert system in the Maintenance Activity Module, for example. It must have available aircraft historical data, personnel training and qualification data, flight activity data, and asset status data to be of real value to MCCs.

Applying the same priority stated in "C. OASIS MODULE DESCRIPTIONS" on page 65, the human resources modules should be developed first, followed by financial management modules, material management modules, and finally the utility module. However, visibility has a lot to do with a system's success with sponsors and acceptance by users. The more people who see and use a system, the higher is the likelihood that it will become accepted and supported. Although in the long run personnel issues will have a dramatic impact on an OMA's ability to perform, those issues seldom receive the sustained visibility that aircraft readiness issues do. Accordingly, the first modules that should

be developed are those that have high visibility in terms of aircraft readiness. Those modules are the Flight Activity Module, the Maintenance Activity Module, and the Asset Management Module. The expert system portion of the Maintenance Activity Module will require data from the Flight Activity Module, the Training and Qualifications Module, and the Asset Management Module, so those modules should be developed in parallel with the ES in the Maintenance Activity Module. Considering the fact that financial management is bound to be consistently important (particularly as funds become fewer and fewer), the Financial Management modules should be developed next. The utility module functions should be developed as needed to support the rest. Finally the Personnel Management Module should be developed. The benefit of the modular organization deserves added emphasis. Each of these modules can be developed independent of the others (with the sole exception of the expert systems), as long as it is developed under the umbrella of an over all plan that will make future integration of the different modules easy. OASIS is such a plan.

Information engineering is the most promising development methodology to use, and is the most consistent with the modular framework proposed. Additionally, taking the evolving prototype approach will allow a system to be developed that meets the real needs of the end-users, not the needs of the users as perceived by a systems developer. In short, build a quick and dirty prototype and get it out to the fleet (OMAs). Let the users propose changes and improvements, make those changes, and repeat the process until an acceptable level of stability is reached, and then go on to the next module. A good place to start would be with CANDES. It already has support and visibility, is already being imple-

mented, and more importantly, is the data collection portion of one of the modules (Flight Activity) recommended above for immediate development. The benefits of just collecting the NAVFLIR data at the source are becoming obvious. Results through January from the first test sites indicate that what used to be a 10-20 percent error rate is now **zero** [Ref. 54]. The aircrew, or whoever enters the flight data, aren't allowed to make errors. The errors are trapped right at the source. This allows all the people who were involved in the post entry checking process to perform other tasks, or to do those other tasks better now that they don't spend as much time fixing errors. That system should now go through user-initiated improvements while the rest of the functions of the Flight Activity Module are added.

### 3. Potential Problems and Benefits

This section will highlight some of the potential problems and pitfalls that must be overcome if OASIS is to be successfully developed and implemented. Some of these issues have been previously mentioned, but they are important enough to warrant additional and separate discussion.

#### *a. Audit Trail and Signature Requirements*

The requirement for an audit trail could be a potential problem. Signatures are required at various points in the use and repair of aircraft. A pilot must sign for the aircraft, an inspector must sign that he has completed the inspection in accordance with applicable instruction, and only designated personnel (typically MCCs) are authorized to release an aircraft to a pilot as safe to fly. Provision must be made for obtaining these signatures, or some other way for these "special events" to be marked must be found. A simple way would be to

issue passwords to those authorized to sign a form. The system would ask for the password anytime someone attempted to complete that block. Each person's password would cause their name to appear in that space. Doubters would ask what is to prevent an unauthorized person from using another's password. The answer is nothing. However, aviation maintenance has always relied on the idea of special trust and confidence when granting the authority to individuals to certify certain events with their signature. That same special trust and confidence would apply to the issuance of passwords. The basic elements of any good password security system would have to be applied, but not in such a way as to undermine that special trust and confidence that is so essential to effective aviation maintenance. For those who remain unconvinced, absolute security can be purchased, but at a price. Signature recognition and verification devices are a possible solution to this problem, in that only with a signature that the system recognizes as appropriate for that event would the event show as completed in the system. It may be impossible to totally eliminate paper from the aircraft flying and maintaining cycle, but it can certainly be reduced.

#### *b. Availability of Experts*

For areas where ESs are appropriate, a potential problem is the difficulty of convincing upper management to let go of their expert for the time it will take to build the system. Inevitably, the expert you need is the one in highest demand [Ref. 58: p 200.]. This hesitancy must be overcome by either 1) convincing upper management that the long term gain far outweighs the short term pain, or 2) getting upper management's bosses to convince them. Another, less optimum solution is to develop the expert system with limited access to the

expert(s). This would increase the number of iterations required, and unnecessarily prolong development.

### *c. Prototype Transition*

Another issue that must be addressed is how and when prototypes, or even fully developed systems (expert or others) built at the Naval Postgraduate School should transition from NPS to full fledged fleet system support. A second part of this issue is what activity in the information systems hierarchy of the Navy is going to take over the support of those systems. Quantity and quality of accompanying documentation will need to be addressed. In other words, just because the system is developed at NPS does not relieve NPS of satisfying the same requirements a commercial contractor would have to meet in fulfilling a contract for the system. (A more compelling reason for turning over a top notch system is the need for NPS students and faculty to practice what is being preached in the information systems curriculum at NPS.) This problem would be effectively answered if NAMO does in fact take on CDA responsibilities for OASIS. Then, NPS-developed applications would have to meet the same requirements as an application sent to NAMO by an OMA.

### *d. Procedure Correction*

Aviation maintenance may benefit from just the process of developing OASIS. We may find, by going through the iterative prototyping process with the end-users, that the way we are doing business now has some basic flaws. As Deming [Ref. 59: pp. 9-10] and others have emphasized, automating a flawed process merely allows the flaws to manifest themselves faster once the system is in operation. This is not to imply that the maintenance process is flawed and

needs to be evaluated. That process is in fact being constantly evaluated under the most demanding conditions, namely, daily flight operations. However, if we have accepted faulty procedures as the way some things must be done, attempting to automate those procedures in the literal and inflexible realm of computerized information systems may require that we finally change and maybe even streamline those procedures.

## E. SUMMARY

In summary, strategic planning for OMAs must precede strategic information systems planning. Those strategic information plans are then translated into functional requirements. Finally an information system that, through this top-down process, meets the information needs of the organization, is planned, developed and implemented. Information engineering provides an organized and formal method to perform the top-down information analysis necessary to develop a flexible and responsive information system.

NALCOMIS, developed using the traditional problem solving approach to information systems development, attempted to satisfy all the requirements in one system developed all at one time. For whatever reason, loss of funding, taking too long, or too many changes to the specific requirements, it has not been fielded for the OMAs.

Contrasted with the traditional problem solving approach is that of iterative prototyping. This maintains continuous end-user involvement, and coupled with information engineering, has the potential to deliver, in a start-small-and-grow fashion, the tools OMA managers need to effectively apply their resources to accomplishing CNO readiness and safety goals.

The preliminary module descriptions and implementation plan for OASIS has been presented. The preliminary plan recommends developing first those modules that will have the greatest impact in terms of both visibility and usefulness. Finally, the potential pitfalls of an audit trail, signature requirements, expert availability, prototype transition, post deployment software support were highlighted so that they can be avoided.

# V. RECOMMENDATIONS, FURTHER RESEARCH, AND CONCLUSIONS

## A. RECOMMENDATIONS

Even though this entire proposal is a recommendation of how to fill the automated information management void at OMAs, there are still a few recommendations that will help focus the effort of those that follow. The first is that since we have within the Navy the resources to develop OASIS, it should be developed within the Navy. We have the people with the knowledge of aviation maintenance. We have a growing number of people with information systems knowledge. Furthermore, advancing technology is providing us with the hardware and software advances that make developing OASIS not only imperative, but, relative to 15 years ago, easy.

The second recommendation is not original. It is something that information systems developers have learned with painful slowness. **Involve** the users. This means more than asking them what they want. It means getting them involved on day one and keeping them involved throughout the life of the system. As discussed, the most effective way to do that is through iterative prototyping. Therefore, do not waste any time fielding a prototype and using iterative prototyping to keep the users involved.

The third recommendation derives from the fact that the users of OASIS are not those at the IMAs, not those in supply, not those at higher level commands, but the maintainers at the OMAs. Accordingly, the requirements that determine

the functions OASIS performs, and the order and manner in which those functions are developed must come from the OMA maintenance professionals. Do not let OASIS be driven by the reporting requirements of higher authority or by the interface requirements of any other system. Those are all only small parts of OASIS. OASIS is for "the guys in the trenches."

The fourth recommendation is that once aviation maintenance officers have been selected to attend the Naval Postgraduate School they should be contacted and briefed about the OASIS project and the potential for them to get an early start on their thesis by working on some part of OASIS. This can be best accomplished through liaison between the OASIS developers and the aviation maintenance officer detailer. This is not to suggest excluding anyone else from working on a part of OASIS, only to suggest that the aviation maintenance officer community is small enough that marketing OASIS as thesis material is manageable. The student will benefit from knowing the topic of his/her thesis and having a ready topic for class projects and papers. The OASIS project will benefit from having people work on the project who do not have to learn aircraft maintenance in the Navy. OASIS will also benefit from keeping academia involved and thereby ensuring that the "leading edge" of information systems technology is applied to OASIS.

## B. AREAS FOR FURTHER RESEARCH

This section addresses several areas that warrant further research. Each module is itself at least one project, and in most cases several, that will need further research. Throughout this thesis, areas were pointed out that would need

additional study or effort. Those presented here are in addition to those already discussed, or are important enough to repeat.

### 1. OMA Information Resource Management

One of the alternatives to a standardized system such as OASIS is for each OMA to "do its own thing" with respect to information management. One argument in favor of such an approach is that in spite of the NAMP standard, every OMA is a unique organization with its own style of doing things. Another is that by pushing a standard system we would be removing some of each CO's leeway in managing his OMA. On the other hand, the question of whether OMAs have or will ever have enough knowledge of information systems to do their own planning needs to be answered. Also important is the question of whether OMAs should be doing their own IRM planning and IS development. Further study into how IRM should fit within an OMA's management could possibly resolve these questions. The points of view on these issues will range from the OMAs, who are tired of waiting, to Operational Commanders (who would probably say an OMA is there to fight, not build computer systems.).

### 2. Evaluation criteria.

To avoid falling into the trap of pouring more and more resources into a project that has already failed, some criteria to measure the success of OASIS should be decided upon at the outset. Because our real customers are the end-users in the OMAs around the world, their satisfaction should be the primary measure of success. However, being within budget and on schedule are also important criteria. How to measure the chosen criteria should be an early decision so that tracking of them can start immediately. Limits should be established be-

yond which specific action is taken, e.g., at ten percent late the project is killed. What these criteria should be, and what limits should be established falls in the field of software engineering, and is certainly an area for further study.

### 3. Knowledge Acquisition

There are more than one type of aircraft in the Navy. Each has its own maintenance experts, and even among those experts there will be differences of opinion (and heuristics) about the way to solve a particular problem. Which of these experts should become the expert for an ES? Who decides who the expert is? Should there be more than one expert consulted while building an ES? Once chosen, will "their" ES be accepted by the other experts who were not chosen, and thus by the fleet? Can the experts, already in short supply, be made available for the time it takes to build the ES? How long will it take to acquire the knowledge of the expert(s)? These are all questions that must be answered for an ES to be developed. Finding the answers is itself a topic of thesis proportions, and worthy of further study.

### 4. Data collection

The user interface of OASIS must be studied. There are a wide variety of styles available. Some people prefer typing while others prefer using a mouse or track ball. Which will gain more user acceptance, or should both be offered? Should the video screens for data collection look exactly like the paper forms in use now, or should the data be collected by having the user respond to a series of questions. Will the answers be typed in by the user, or selected from a list? Will a paper copy be required? What backup method will be used? How extensive and sophisticated should the security system be? How many data collection

points should there be (a subject for queuing theory) to satisfy the peaks and troughs of data entry, e.g., when ten aircrew want to fill in their flight data? Will the aircrew even have to fill it in anymore? Similar surges in data entry can be expected near shift changes and meal times as maintenance personnel try to complete their "paperwork." Since the user interface is in reality the most visible part of the system to the user, extensive study should be done to determine the optimum mix of available options.

### 5. Implementation and Post Deployment Software Support

Although mentioned earlier, this issue is important enough to be addressed specifically. The exact method of implementation for OASIS needs to be studied. Over 400 OMAs will eventually benefit from OASIS (or a similar system). They can not all be a prototype site. Should use of OASIS be mandatory or optional? What is the best method of implementation to ensure its effective use? User involvement can only go so far with so diverse and disbursed a group of end-users.

Current IS assets at OMAs range from very basic combinations of hardware and software to ones that are very sophisticated. An analysis of the expected hardware and software requirements for OASIS must be performed. Then those requirements must be compared to what OMAs already have. Finally, an acquisition plan must be developed to ensure that all OMAs have the necessary hardware and software to implement OASIS before OASIS is available to them. Considering the budget process in DOD, this plan must be developed early in the OASIS development in order to have the funding approved by the time OASIS is ready for implementation.

The point at which an information system is delivered to a customer is when the major part of the work on that system begins. The system must be maintained, changes in the customer's procedures must be incorporated, and errors that are found after delivery must be fixed. If a system takes one year to develop and deliver, and it is expected to be in use for nine additional years, then ninety percent of its life is post-delivery. Hardware is not normally the problem; software is. How OASIS will be supported needs to be determined. Alternatives should be identified, evaluated, and finally a decision must be made early enough in the development so that the support can be in place and ready when OASIS is deployed. This will mean keeping the PDSS activity (or activities) as involved as the end-users, if not more so, throughout the development. With respect to expert systems, who will maintain the knowledge base? Will we have to dedicate an expert to it, or can experts be consulted as needed by a knowledge engineer? When changes have been made, who will authorize distributing them to the fleet, and how will it be done? These issues must all be resolved before OASIS is ready to be implemented, and are ideal candidates for further study.

#### 6. OASIS at AMO School

The Navy's school for Aviation Maintenance Officers could play a role in the development and support of OASIS. As the new maintenance officers go through this school they could learn how OASIS works, and not have to learn by trial and error once at an OMA. Additionally, since the school is staffed and taught by fleet experienced maintenance personnel, their ideas and suggestions would be invaluable to both the initial development and the post deployment support. They, unlike their peers still at OMAs, may be able to devote time to

such a project without detracting from their performance. Encouraging them to constructively critique OASIS and become actively involved in the system could help overcome their reluctance, while still at an OMA, to 1) put themselves on report by advertising problems, and 2) take the time from their hectic crisis-ridden daily jobs to submit changes to the systems that are supposed to help them.

## C. CONCLUSIONS

The strategic goal of an Organizational Maintenance Activity is to achieve and maintain Chief of Naval Operations standards of readiness and safety. Achieving that goal requires planning the effective acquisition and use of resources. One of the resources is information. Not only is information a resource, but also timely, accurate and relevant information is vital to effective management of the other resources, specifically aircraft, people, equipment and money.

OMAs are tasked with managing billions of dollars of physical assets, hundreds of people and their training, and tremendous inventories of parts, supplies, publications and equipment with no modern management tools to help. The need to manage the information resources of aviation maintenance managers was formally recognized when NALCOMIS was conceived. Today, the only question remaining is the specific information system that will provide the modern tools, and when it will actually be implemented at OMAs.

Information systems technology has made phenomenal advances in the past 15 years. We in aviation maintenance must capitalize on advances in structured analysis methods, information engineering techniques and artificial intelligence tools. Failure to do so would be a tragedy.

Much work has gone into the assorted information systems used at different aviation maintenance levels and activities. Several of these systems can provide valuable information to OMAs and should be tasked with doing so in a form that can be used by OASIS.

Undertaking to develop an information system complex enough to support the information needs of Organizational Maintenance Activities is an ambitious objective. It has been tried before. However, by reducing the project to modules of manageable size, and applying the concept of evolutionary prototyping, OMAs will finally reap some benefit. As more modules are developed, the full impact of managing information effectively will be realized. We must fill the void intelligently, but QUICKLY. OASIS is the initial step.

## APPENDIX A. ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **AEMS** | Aircraft Engine Management System |
| **AMMRL** | Aircraft Maintenance Material Readiness List |
| **AMO** | Assistant Maintenanace Officer |
| **AMRR** | Aircraft Material Readiness Report |
| **ARS** | Aerial Refueling Stores |
| **ASETS** | Aviation Squadron Enlisted Training System |
| **ATSS II** | Aviation Training Support System--Phase II |
| **AV-3M** | Aviation Maintenance and Material Management |
| **BOR** | Budget OPTAR Report |
| **CANDES** | Computer Aided NAVFLIR Data Entry System |
| **CDA** | Central Design Activity |
| **CD-ROM** | Compact Disk-Read Only Memory |
| **CIMP** | Component Information Management Plan |
| **CNO** | Chief of Naval Operations |
| **CO** | Commanding Officer |
| **CONUS** | Continental United States |
| **DD/DS** | Data Dictionalry Directory System |
| **DOD** | Department of Defense |
| **DON** | Department of the Navy |
| **DSS** | Decision Support System |
| **ES** | Expert System |
| **FRS** | Fleet Readiness Squadron |
| **IE** | Information Engineering |
| **IMA** | Intermediate Maintenance Activity |
| **IMRL** | Individual Material Readiness List |
| **IRSTRATPLAN** | Department of the Navy (DON) Strategic Plan for Managing Information and Related Resources (IRSTRATPLAN) |

| | |
|---|---|
| **IS** | Information System |
| **LAN** | Local Area Network |
| **LCM** | Life Cycle Management |
| **MAF** | Maintenance Action Form |
| **MC** | Maintenance Control |
| **MCC** | Maintenance Control Chief |
| **MDCS** | Maintenance Data Collection System |
| **MDS** | Maintenance Data System |
| **MIS** | Management Information System |
| **MO** | Maintenance Officer |
| **MPA** | Manpower Authorization |
| **MMCO** | Maintenance Material Control Officer |
| **MRS** | Management Reporting System |
| **NADEP** | Naval Aviation Depot |
| **NADIS** | Naval Aviation Depot Information System |
| **NALDA** | Naval Aviation Logistics Data Analysis |
| **NAMO** | Naval Aviation Maintenance Office |
| **NAMP** | Naval Aviation Maintenance Program |
| **NAMSO** | Naval Aviation Maintenance Support Office |
| **NALCOMIS** | Naval Aviation Logistics Command Management Information System |
| **NALCOMPT** | Navy Comptroller |
| **NAVAIR** | Naval Air Systems Command |
| **NAVFLIR** | Naval Flight Information Record |
| **NAVMASSO** | Navy Management Systems Support Office |
| **NAVSEALOGCEN** | Naval Sea Logisitics Center |
| **NAVSO** | Navy Staff Office |
| **NAVSUP** | Naval Supply Systems Command |
| **NMPC** | Naval Military Personnel Command |
| **NOAP** | Naval Oil Analysis Program |
| **NRMM** | NALCOMIS Repairables Management Module |

| | |
|---|---|
| **OASIS** | Organizational Activity Standard Information System |
| **OPTAR** | Operating Target |
| **OPSO** | Operations Officer |
| **OMA** | Organizational Maintenance Activity |
| **PMA** | Program Manager Air |
| **PMS** | Planned Maintenance System |
| **POE** | Planned Operating Environment |
| **RFI** | Ready For Issue |
| **ROMC** | Representations, Operations, Memory aids, Control mechanisms |
| **SAF** | Support Action Form |
| **SECA** | Support Equipment Controlling Activity |
| **SERMIS** | Support Equipment Resources Management Information System |
| **SFO/EDL** | Summary Filled Order Expenditure Difference Listing |
| **SQMD** | Squadron Manning Document |
| **SSC** | Supply Support Center |
| **SUADPS** | Shipboard Uniform Automated Data Processing System |
| **TD** | Technical Directive |
| **TMS** | Type, Model, Series |
| **TPS** | Transaction Processing System |
| **TYCOM** | Type Commander |
| **UADPS** | Uniform Automated Data Processing System |
| **VALSPECS** | Validation Specifications |
| **VAMOSC** | Visibility and Management of Operating and Support Costs |
| **VIDS** | Visual Information Display System |
| **VIDS/MAF** | Visual Information Display System Maintenance Action Form |
| **XCON** | The Expert Configurer (used by Digital Equipment Corp.) |
| **XO** | Executive Officer |

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